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## THE BILE FACTOR IN PANCREATITIS

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Among the many explanations of the cause of pancreatitis, the one attributing the condition to a reflux of bile into the pancreatic duct has seemed the most plausible to the greatest number of clinicians and surgeons. The reason for this is probably that the process, seemingly, may take place in man and that it deals with factors concerning which physicians are already acquainted. We have approached the problem of bile as the causative factor in acute and chronic pancreatitis from two aspects, the anatomic and the experimental. The investigation of the problem was suggested several years ago by Dr E S Judd, and during the last six years the condition of pancreatitis has been studied in its general aspects, and several lines of investigation with regard to the most plausible features have been followed. In this article only the possible relation of bile to pancreatitis will be considered. The results of other studies will be published later.

Extensive investigations have been carried out with regard to the cause of pancreatitis. The most complete recent literary review of the subject was published by Sweet<sup>1</sup>. An important percentage of such reviews deal with the bile factor as the cause. Ample evidence<sup>2</sup> is at hand to prove that cholecystitis and chronic and acute pancreatitis coexist in a large percentage of cases. Many statistics have been accumulated to show this,<sup>3</sup> but the cause of such coexistence is still unknown. Two possibilities have been suggested with regard to this relationship and bile as the cause of pancreatitis. (1) A small gallstone or other mechanical obstruction may block the exit of the

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1 Sweet, J E. The Surgery of the Pancreas, *Internat Clinics* 4 293-357, 1915

2 Mayo, W J. The Surgical Treatment of Pancreatitis, *Surg, Gynec & Obst* 7 607-613, 1908

3 Egdahl, A. A Review of One Hundred and Five Reported Cases of Acute Pancreatitis, with Special Reference to Etiology, with Report of Two Cases, *Bull Johns Hopkins Hosp* 18 130-136, 1907

common bile duct so that it forms a continuous channel with the pancreatic duct and allows bile to infiltrate the pancreas, and (2) the sphincter at the duodenal end of the common bile duct may contract and produce the same condition

The possibility that gallstones lodged in the ampulla of Vater could cause disease of the pancreas by obstruction of the main pancreatic duct was suggested by Lancereaux.<sup>4</sup> Opie<sup>5</sup> asserted that ligation of both pancreatic ducts will cause hemorrhagic pancreatitis, and he reported a case of acute hemorrhagic pancreatitis, with gallstones in the common bile duct near the ampulla causing obstruction, bile had not entered the duct of Wirsung nor was the duct dilated. He collected reports of seven similar cases from the literature and concluded, "The lodgment of a stone near the orifice of the common bile duct, where it may at the same time compress or occlude the pancreatic duct, is not uncommonly the cause of pancreatic lesions and disseminated fat necrosis." In the same year, he<sup>6</sup> reported another case of hemorrhagic pancreatitis in which a calculus, 3 mm in diameter, was found impacted in the apex of the ampulla of Vater, the diameter of which was 1 mm. The duct of Wirsung opened 7 mm from the apex of the ampulla so that the pancreatic and common bile ducts were converted into one continuous channel. To prove his contention that bile was the cause of the acute pancreatitis, he injected bile into the main pancreatic duct of dogs, and produced acute pancreatitis in all the animals. Similar experiments have been carried out by Flexner,<sup>7</sup> Cooke and Whipple,<sup>8</sup> Polya,<sup>9</sup> Oser,<sup>10</sup> Binet and Brocq and others,<sup>11</sup> who produced similar conditions in

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4 Lancereaux, E. *Traite des maladies du foie et du pancreas*, Paris, Dom, 1899

5 Opie, E. L. The Relation of Cholelithiasis to Disease of the Pancreas and to Fat Necrosis, *Am J Med Sc* **121** 27-43, 1901

6 Opie, E. L. The Etiology of Acute Hemorrhagic Pancreatitis, *Bull Johns Hopkins Hosp* **12** 182-188, 1901

7 Flexner, Simon. Experimental Pancreatitis, *Johns Hopkins Hosp Rep* **9** 743-771, 1900, Experimental Pancreatitis, *Univ Penn Med Bull* **14** 193, 1901-1902, The Constituent of the Bile Causing Pancreatitis and the Effect of Colloids upon Its Action, *J Exper Med* **8** 167-177, 1906

8 Cooke, J. V., and Whipple, G. H. Proteose Intoxications and Injury of Body Protein. IV. The Metabolism of Dogs with Sterile Abscess, Pancreatitis, and Pleuritis, *J Exper Med* **28** 223-241 (Aug.) 1918

9 Polya, E. A. Zur Pathogenese der acuten Pankreasblutung und Pankreasnekrose, *Berl klin Wchnschr* **93** 1562-1565, 1906

10 Oser, L. Die Erkrankungen des Pankreas, Wien Holder, 1898

11 Binet, L., and Brocq, P. Reproduction experimentale de la pancreatite hemorrhagique avec steato-necrose et du pseudokyste pancreatique par l'injection de sels de calcium dans le canal de Wirsung, *Compt rend Soc de biol* **72** 341-342, 1920, La rôle du suc intestinal dans la reproduction experimentale de la pancreatite hemorrhagique avec steato-necrose, *ibid* **72** 340-341, 1920, Brocq, P., and Morel, L. Le rôle de la bile dans la reproduction experimentale des pan-

the pancreas, not only with bile but with many other substances, such as gastric and intestinal juice, hydrochloric acid and calcium chlorid Flexner went farther and proved that taurocholate, when injected into the pancreatic duct, was more active than glycocholate, and that colloids, such as mucin, agar and gelatin, modified the irritative action of bile He suggested that when bile is imprisoned in the gallbladder as the result of inflammatory processes, the composition changes in favor of the mucin constituent, thus reducing the diffusibility of the salts Therefore, theoretically, at least, such bile forced into the pancreatic duct would be less liable to produce acute pancreatitis Nordmann<sup>12</sup> realized the danger of the injection technic, and in experiments on dogs closed the ampulla of Vater by purse-string suture Jaundice without hemorrhagic pancreatitis occurred, even though the pancreatic duct was dilated with bile, but when he introduced virulent organisms into the common bile duct of such dogs, acute hemorrhagic pancreatitis developed

The possible importance of the sphincter at the duodenal end of the common bile duct, which is a definite anatomic and physiologic structure, in pancreatitis, was suggested by Archibald<sup>13</sup> He says that he has produced acute hemorrhagic pancreatitis by introducing into the gallbladder of cats, bile or bile salts incubated for various lengths of time with bacteria, and by forcing this to enter the pancreatic duct by spasm of the sphincter, owing to sudden rise of pressure in the gallbladder from 200 to 700 mm of water, or to application of hydrochloric acid (5 to 15 per cent) to the mucous membrane of the duodenum The animals lived from thirty minutes to several days Necropsy of those that lived a few hours revealed acute hemorrhagic pancreatitis and multiple focal abscesses in the liver, of the others, various degrees of

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creatitis hemorrhagiques avec steato-necrose, *ibid* **71** 371-372, 1919 Brocq, P Note sur la realisation experimentale de la pancreatite hemorrhagique par stase duodenale, *Bull et mem Soc de Chir de Paris* **47** 7-8, 1921 Hewlett, A W On the Occurrence of Lipase in the Urine as a Result of Experimental Pancreatic Disease, *J Med Research* **11** 377-397, 1904 Hlava, J L'hemorrhagie, l'inflammation et la gangrene du pancreas, *Praze*, 1898 Petersen, W, Jobling, J W, and Eggstein, A A Serum Changes and the Cause of Death in Experimental Pancreatitis Studies on Ferment Action XXX, *J Exper Med* **23** 491-498 (April) 1916 Speese, J, Sailer, J, and Torrey, R Further Experiments in the Toxemia of Experimental Acute Pancreatitis, *Tr Ass Am Phys* **26** 446-450, 1911

12 Nordmann, O Experimente und klinische Betrachtungen uber die Zusammenhange zwischen acuter Pankreatitis und Erkrankungen der Gallenblase, *Arch f klin Chir* **102** 66-120, 1913

13 Archibald, E, and Mullally, E J Some Observations on the Diagnosis and Treatment of Subacute and Chronic Pancreatitis, *Canad M A J* **3** 87-97, 1913, Archibald, E A General Consideration of Pancreatitis, *Internat Clinics* **2** 1-20, 1918, The Experimental Production of Pancreatitis in Animals as the Result of the Resistance of the Common Duct Sphincter, *Surg, Gynec & Obst* **28** 529-545 (June) 1919

In order to verify the discrepancies reported concerning the exact relations of the common bile duct to the duct of Wirsung, human specimens from 200 consecutive necropsies were carefully dissected. At first the dissection was carried out in fresh preparation, but this method was soon discarded because of the difficulty encountered in preserving the delicate membranous septum which often separates the duct of Wirsung at the duodenal end from the common bile duct<sup>21</sup>. The duodenum and pancreas were removed in toto and the duodenum was opened anteriorly. The common bile duct was then incised at a point near the cystic duct and opened to the duodenal end. By cutting the pancreas transversely, the main pancreatic duct was exposed and carefully dissected up to a point about 2 cm. from the wall of the duodenum. After the specimen had been fixed in liquor formaldehydi for twenty-four hours, the duct of Wirsung was again followed to the wall of the duodenum. The opening was ascertained by carefully passing a flexible wire, about 2 mm. in diameter, with a rounded polished end, into its

TABLE 1—DATA ON THE RELATION OF THE DUCT OF WIRSUNG TO THE COMMON BILE DUCT

Group	Location of Opening of Pancreatic Duct	Number of Specimens	Percentage	Distance from the Apex of the Ampulla of Vater to the Dividing Septum in Mm.							
				3	4	5	6	7	8	9	10
1	Separately into duodenum	62	31								
2	2 mm. from the apex of ampulla of Vater	90	45								
3	3 mm. to 10 mm. from the apex of the ampulla of Vater	40	20	28	5	3	0	1	2	0	+1
4	Duct absent or reduced to fibrous cord	8	4								
Total		200									

lumen, and allowing it to follow the course of least resistance until it reached the exit. Careful measurements were taken of the distance of the opening from the duodenal end of the common bile duct. To prove that the wire had not deviated from the lumen of the duct, various procedures were used, such as injecting methylene blue into the duct and subsequently laying it open and examining the surrounding tissues.

The results obtained may be grouped thus: (1) Both ducts empty into the duodenum separately, contiguous to each other, or at separate points (Figs. 1 and 2), (2) both ducts are contiguous and their extreme ends open into the ampulla from 1 to 2 mm. from the apex, (3) the ducts empty into a common ampulla from 1 to 10 mm. from the apex, and (4) the duct of Wirsung is reduced to a fibrous cord or absent.

It is evident that the common bile duct and the pancreatic duct could be converted into a continuous channel by a blockage of the exit of the

21 Oneto, A. *Anatomia del duodeno y pancreas*, *Semana med.* 1920, p. 27

ampulla only in Group 3 (Table 1), in which the two ducts drain into the duodenum through a common opening, and even in this group the process can only be brought about in cases in which the pancreatic duct empties into the ampulla at a greater distance from the exit than the diameter of the common opening. The average diameter of the ampulla is from 2.5 to 3.5 mm. Thus a calculus must be 4 mm in diameter before it can cause obstruction, except in rare instances. A calculus, 2 mm or less in diameter, may obstruct but eventually it will force

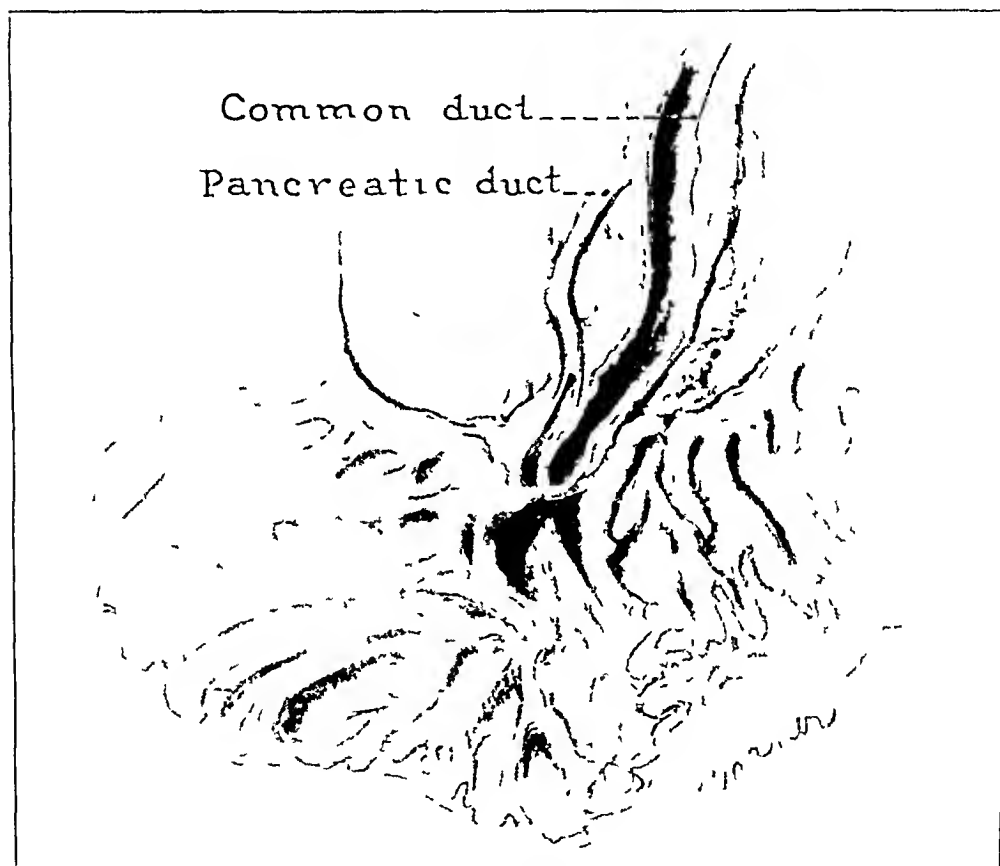


Fig 1—Entrances of the common bile duct and pancreatic duct into the duodenum. It is impossible for the ducts to be converted into a continuous channel when this relationship exists.

its way through. It is common experience to find gallstones larger than this in the duodenum. It should also be noted that the dimensions of the ampulla and the ducts entering it are often such that a calculus which would become impacted would obstruct both ducts and not convert them into a continuous channel. Of the 20 per cent of our specimens in which the two ducts entered together, in twenty-eight instances (14 per cent), the opening of the duct of Wirsung was 3 mm from the apex and in five (25 per cent), 4 mm from the apex.



In these instances reflux of bile into the pancreatic duct because of obstruction would not be possible. This leaves a total of 35 per cent of cases in which it would be anatomically possible for obstruction of the exit of the ampulla to convert the two ducts into a continuous channel and allow bile to pass into the pancreatic duct (Fig. 3).

The sphincter at the duodenal end of the common bile duct has been proved anatomically and physiologically to be a definite structure. Little is known with regard to its physiologic mechanism. We have found it difficult to obtain definite data concerning its function and its physiologic importance.<sup>22</sup> Our observations, based on the histologic examination of hundreds of sections obtained from fifteen species of animals<sup>23</sup> and a physiologic study<sup>24</sup> of ten species of animals, incline us to believe that clinical imagination had greatly preceded demonstrated facts. Our data on this subject will be presented in a future report.



Fig. 2—Specimen illustrating the anatomic relation shown in Figure 1, which relationship existed in 31 per cent of the 200 specimens.

The idea that the sphincter of the common bile duct, by contracting, might convert it and the pancreatic duct into a continuous channel is novel and interesting. However, in order to accomplish this, the sphincter would have to be located around the exit of the ampulla and distal to the opening of both ducts, and even then the reflux of bile into the pancreatic duct could occur only if both ducts opened into the ampulla, which in our series occurred in 20 per cent.

<sup>22</sup> Mann, F. C. Unpublished data.

<sup>23</sup> Mann, F. C. A Comparative Study of the Anatomy of the Sphincter at the Duodenal End of the Common Bile Duct with Special Reference to Species of Animals Without a Gallbladder, *Anat. Rec.* **18**: 355-360, 1920.

<sup>24</sup> Mann, F. C. A Study of the Tonicity of the Sphincter at the Duodenal End of the Common Bile Duct, with Special Reference to Animals Without a Gallbladder, *J. Lab. & Clin. Med.* **5**: 107-110 (Nov.) 1919.

While Glisson<sup>25</sup> believed that a sphincter existed at the end of the common bile duct it was first described by Gage,<sup>26</sup> who studied the sphincter in the cat, and found sphincters around the pancreatic and common bile ducts, and one group of muscle fibers passing around both ducts

Oddi<sup>27</sup> made an extensive comparative anatomic and physiologic study of the sphincter, employing many species of animals, but aside

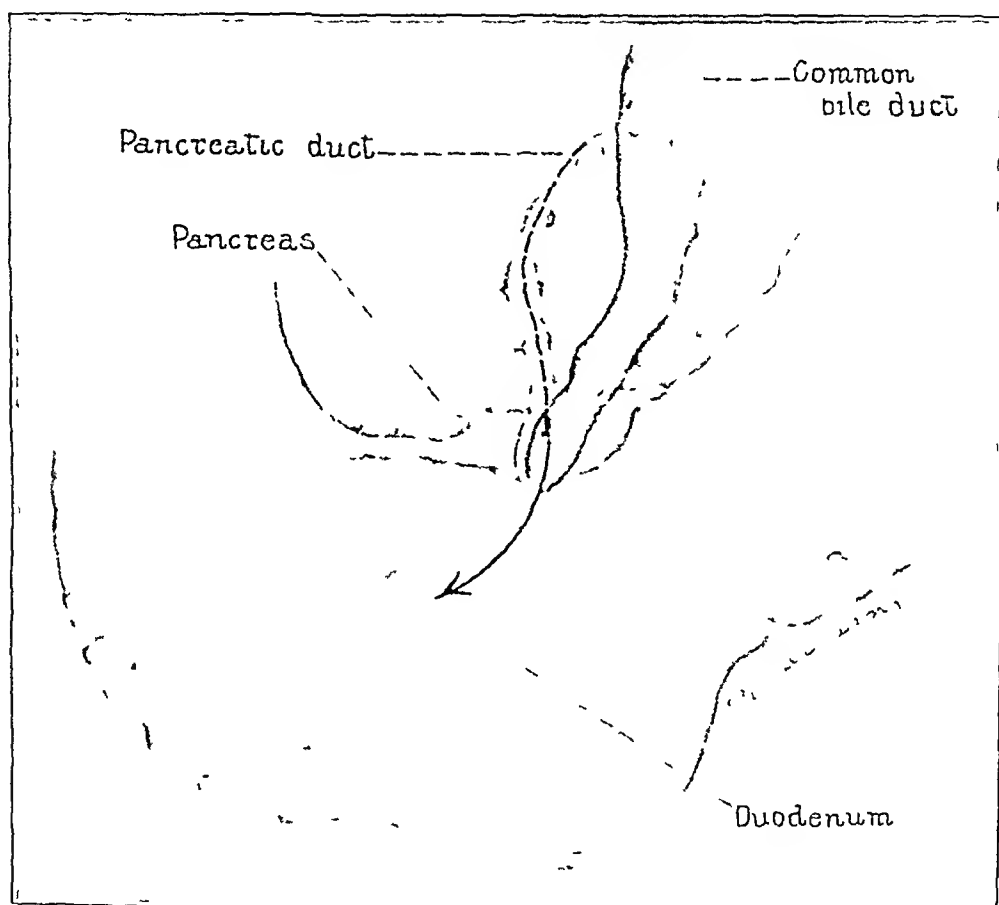


Fig 3—Entrance of the common bile duct and pancreatic duct into the duodenum through a common opening, which arrangement occurred in 20 per cent of the specimens

from assigning a special sphincter to the duct of Wirsung, he did not study especially the relation of the sphincter of the common bile duct

25 Glisson, quoted by Oddi Arch ital de biol 8 317-322, 1887

26 Gage, S H The Ampulla of Vater and the Pancreatic Ducts in the Domestic Cat (*Felis domestica*), Am Quart Micr J 1 128, 169, 1879

27 Oddi, R D'une disposition a sphincter speciale de l'ouverture de canal choledoque, Arch ital de biol 8 317-322, 1887, Sulla tonicita dello sfintere del coledoco, Arch per le sc med 12 333-339, 1888

to the pancreatic duct Hendrickson<sup>28</sup> studied the sphincter in man, in the dog, and in the rabbit His specimens show muscle fibers surrounding both the common bile duct and the duct of Wirsung All observers note a marked individual variation of the disposition of the muscle fibers constituting the sphincter Our data verify the observations of variability

The observations we have made on the histology of the sphincter of the common bile duct, which are particularly applicable to this subject, have to do with the disposition of the muscle fibers of the



Fig 4—Photomicrograph of the common bile duct (a) and pancreatic duct (b) just distal to the point at which they have pierced the muscularis of the duodenum The bundles of smooth muscle fibers pass around each duct separately, some of them pass around both ducts These muscle fibers interlace intimately and if they should contract as a whole, both ducts would be closed,  $\times 20$

sphincter in man with regard to the duct of Wirsung As we have indicated, if Archibald's theory is correct, the sphincter must be placed distal to the entrance of both ducts in the ampulla A careful

28 Hendrickson, W F A Study of the Musculature of the Entire Extra-hepatic Biliary System, Including that of the Duodenal Portion of the Common Bile Duct and of the Sphincter, *Bull Johns Hopkins Hosp* 9 221-232, 1898

examination of serial preparations of the sphincter in man demonstrates that in most instances this is not the case. The usual position of the muscle fibers constituting the sphincter is proximal to the termination of the common bile duct. Furthermore, the muscle fibers not only surround the common bile duct, but some of them pass around the pancreatic duct (Figs 4, 5, 6, 7 and 8) <sup>21</sup> Because of this arrangement, it would seem that contraction of the sphincter would close not only the common bile duct but also the pancreatic duct. There is, however, great variation in the disposition of these muscle fibers. In one instance in man, considerable muscle tissue was found distal to the entrance of the two ducts (Fig 8). If these muscle fibers could



Fig 5—Higher magnification of one area of specimen shown in Figure 4, where the two ducts are contiguous, showing the detail of the course of these muscle fibers,  $\times 50$

contract separately, the two ducts would be converted into a continuous channel. In another instance the two ducts joined definitely on the gland side of the sphincter. These observations show that the usual position and arrangement of the sphincter is such that it is not possible for it to convert the ducts into a continuous channel. However, since there is so much variation in the relation of the different structures in connection with this area, there is always the possibility that in a few instances the sphincter might close the exit of the ampulla.

It has been clearly demonstrated that the injection of bile into the pancreatic duct with a syringe will cause acute pancreatitis and death in

a large percentage of cases. However, the injection of an irritating fluid like bile, with a syringe, where a high pressure is developed, produces definite trauma to the gland. It seems to us that before drawing the inference that the condition of the pancreas following intraductal injection of bile under high pressure is identical to the spontaneous cases of pancreatitis observed in man, it would be necessary to determine (1) the maximal pressure at which the existing physiologic mechanism could inject the bile into the pancreas, and (2) whether



Fig 6—Photomicrograph of the common bile duct and pancreatic duct from the series shown in Figure 4, just before the exit of both ducts through a common opening into the duodenum. The ducts are still separated and surrounded by the three groups of muscle fibers,  $\times 20$

pancreatitis could be produced by the injection of sterile bile under this pressure.

The pressure in the common bile duct is due to three factors (1) the secretory pressure of the liver, (2) the contractile pressure of the gallbladder, and (3) the mechanical pressure exerted by the abdominal muscles and diaphragm on the liver and biliary ducts. We have studied the maximal pressure that is produced in the common bile duct by a combination of all these factors and have made an attempt

to analyze and evaluate the component part of each factor. The experiments were performed on dogs with permanent biliary fistulas. All operations were performed under ether anesthesia and with sterile technic.

The technic for making the fistula has been described<sup>29</sup>. Briefly, it consists of two stages: transplanting the duodenum under the skin so that the point of entrance of the duct at the duodenum is very superficial, and second, opening the common bile duct on the surface.



Fig 7—Photomicrograph showing the detail of the course of the three groups of muscle fibers making up the group of fibers termed the sphincter. This is taken at a point where the bundles of muscle fibers are the largest. None of the fibers shown belong to the muscularis of the duodenum,  $\times 50$ .

of the skin. After the wound was healed the following observations were made:

After the preliminary procedure of feeding different kinds of foods, or of fasting, the animal was made comfortable on a table, with the employment of as little restraint as possible. A rubber catheter of

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<sup>29</sup> Mann, F. C. A Technic for Making a Biliary Fistula, *J. Lab. & Clin. Med.* 7: 84-86 (Nov.) 1921.

such a size that it fitted the duct tightly and prevented leakage was inserted into the common bile duct. A glass T-tube was attached to the catheter. To one arm of the T, a rubber tube with a screw clamp was attached, and to the other arm, a straight glass tube. The glass tube was slightly more than 100 cm in length, had an external bore of approximately 2.5 mm, and was graduated in millimeters (Fig 9, *a* and *b*). The zero of the scale was at a level corresponding to a plane passed approximately longitudinally through the center of the liver. The pressure was always recorded in millimeters of bile. An



Fig 8—Photomicrograph through the ampulla, showing the heavy band of muscle fibers surrounding the channel common to the two ducts. If these particular muscle fibers could contract separately, the two ducts would be converted into a continuous channel. However, these muscle fibers seem to be but a continuation of those that pass around both ducts,  $\times 8$ .

objection to this method of estimation is that the specific gravity of bile varies. However, other methods that we tried had a greater possibility for error and were not so simple. The animals were always made comfortable and seemed actually to enjoy the periods of observation. Observations were made on some of the animals from three to four times a week, extending over a period of many months.

Secretory pressure of the liver varies in the different species of animals, in various individuals, and under various conditions, such as

food ingestion We shall report in another study a large number of observations dealing with the effect of various food substances on the secretory pressure of the liver, in this study, only the maximal pressure attainable is of importance

Our records on the maximal pressure produced in the common bile duct of the dog, due to the secretory activity of the liver, contain several hundred observations extending over many months They show that a pressure of 350 mm of bile rarely occurs, and at no time has pressure greater than 375 mm of bile due to the secretory activity of the liver alone been observed The average pressure obtained is

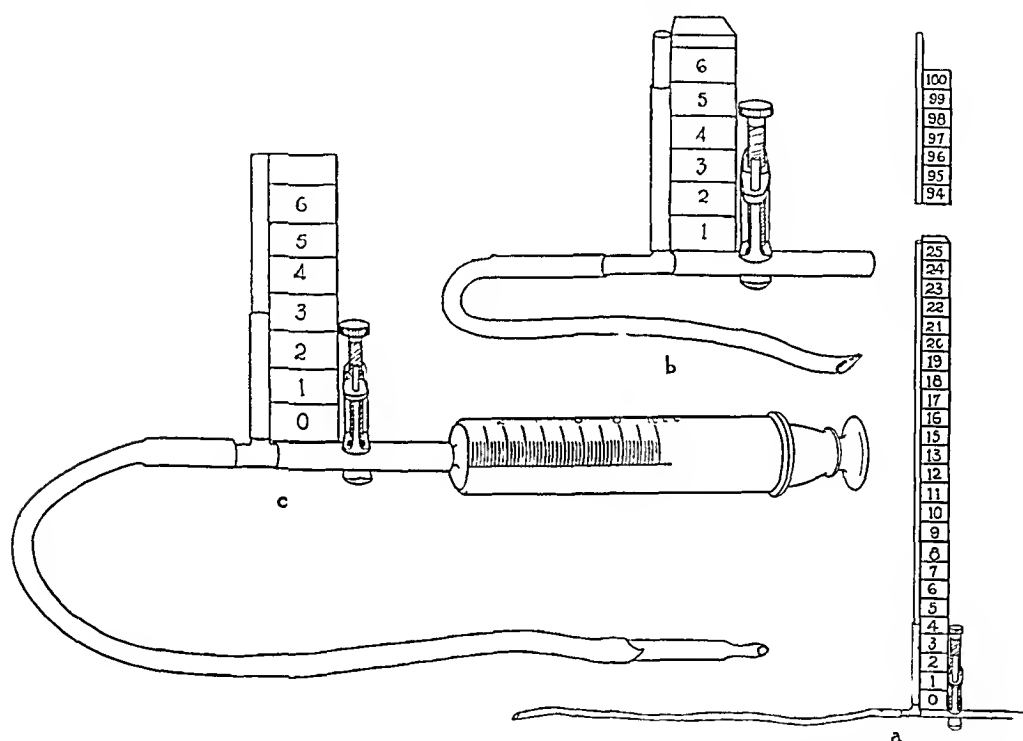


Fig 9—Bile manometer (a) the manometer as a whole, (b) the detail of the manometer as it was used in estimating the pressure in the common bile duct, and (c) the manner in which it was used to inject bile under constant and measured pressure into the pancreatic duct

less than 350 mm This coincides with our published data and the findings of other observers<sup>30</sup>

It is difficult to estimate the part the gallbladder plays in producing pressure in the common bile duct We attempted to estimate the

<sup>30</sup> Herring, P T, and Simpson, S The Pressure of Bile Secretion and the Mechanism of Bile Absorption in Obstruction of the Bile Duct, *Proc Roy Soc, London* **79** 517-532, 1907 Mann, F C, and Foster, J P The Secretory Pressure of the Liver, with Special Reference to the Presence or Absence of a Gallbladder, *Am J Physiol* **47** 278-288 (Nov) 1918 Mitchell, W T, Jr, and Stifel, R E The Pressure of Bile Secretion During Chronic Obstruction of the Common Bile-Duct, *Bull Johns Hopkins Hosp* **27** 78-79 (March) 1916



pressure produced by the contraction of the gallbladder, but this was difficult under conditions approximating the normal. The most satisfactory method, so far as maintaining the physiologic integrity of the mechanism is concerned, consisted in observing the fluctuations in pressure in the tube connected to the common bile duct while we were studying the secretory pressure of the liver. If this pressure is observed carefully as it increases, certain rhythmic variations are noted



Fig 11—Photomicrograph of a section of pancreas illustrated in Figure 10. The specimen was fixed in liquor formaldehydi fifteen minutes after injection. Marked destruction of the pancreatic tissue has occurred,  $\times 50$ .

which are not dependent on respiration or other body movements. The rhythmic variations in pressure are not great and the movements are only approximately constant. They were noted in only a relatively small percentage of observations. They seemed to be caused by the contraction of the gallbladder, they were not noted in animals in which this viscus had been removed. These rhythmic variations in pressure were never noted when the pressure had increased in the tube beyond 340 mm. of bile.

It is not possible to draw definite conclusions from these observations, but when they are considered in connection with other



Fig 10—Pancreas showing the effect of the injection of 10 cc of bile into the anterior pancreatic duct, with a syringe. The time of injection was less than 10 minutes. The center of the lobules are discolored, owing to the rupture of the small pancreatic ducts and infiltration of bile into the center of the lobules.

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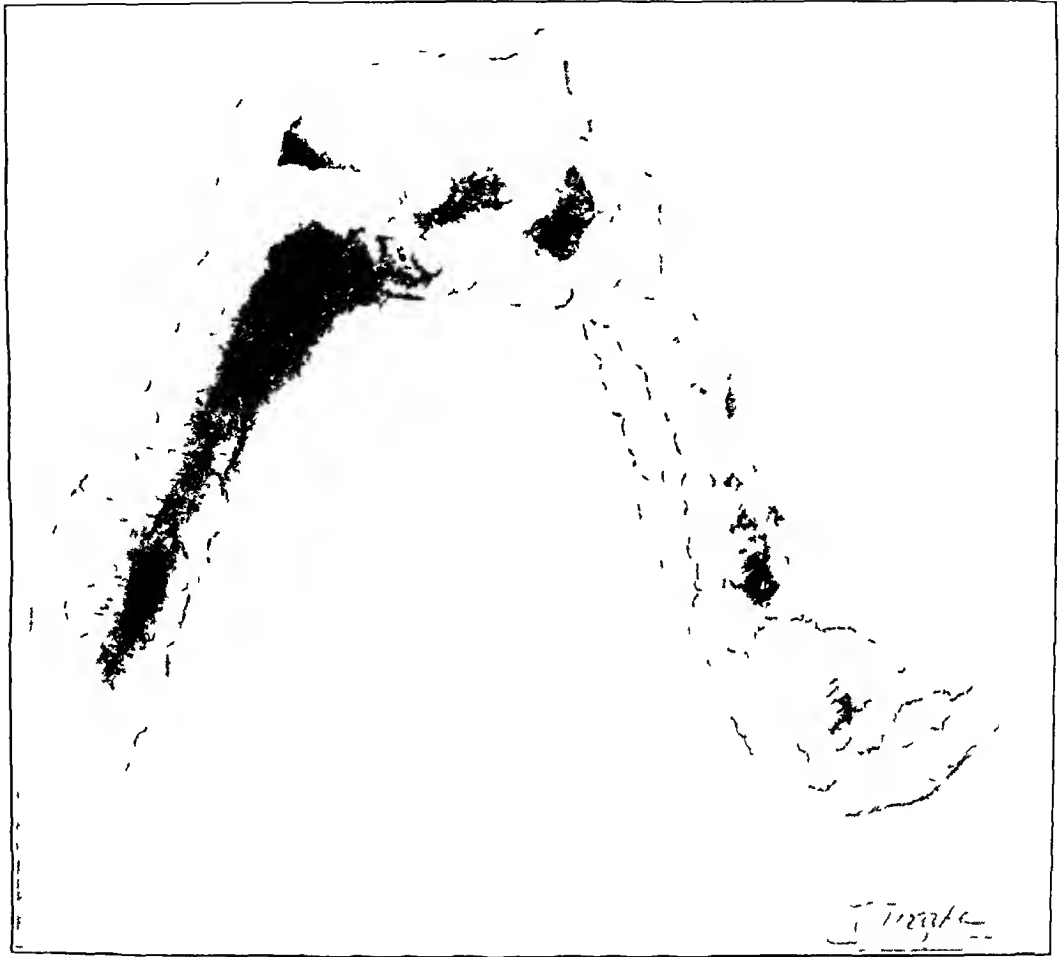


Fig 10—Pancreas showing the effect of the injection of 10 cc of bile into the major pancreatic duct, with a syringe. The time of injection was less than five minutes. The center of the lobules are discolored, owing to the rupture of the small pancreatic ducts and infiltration of bile into the center of the lobules.



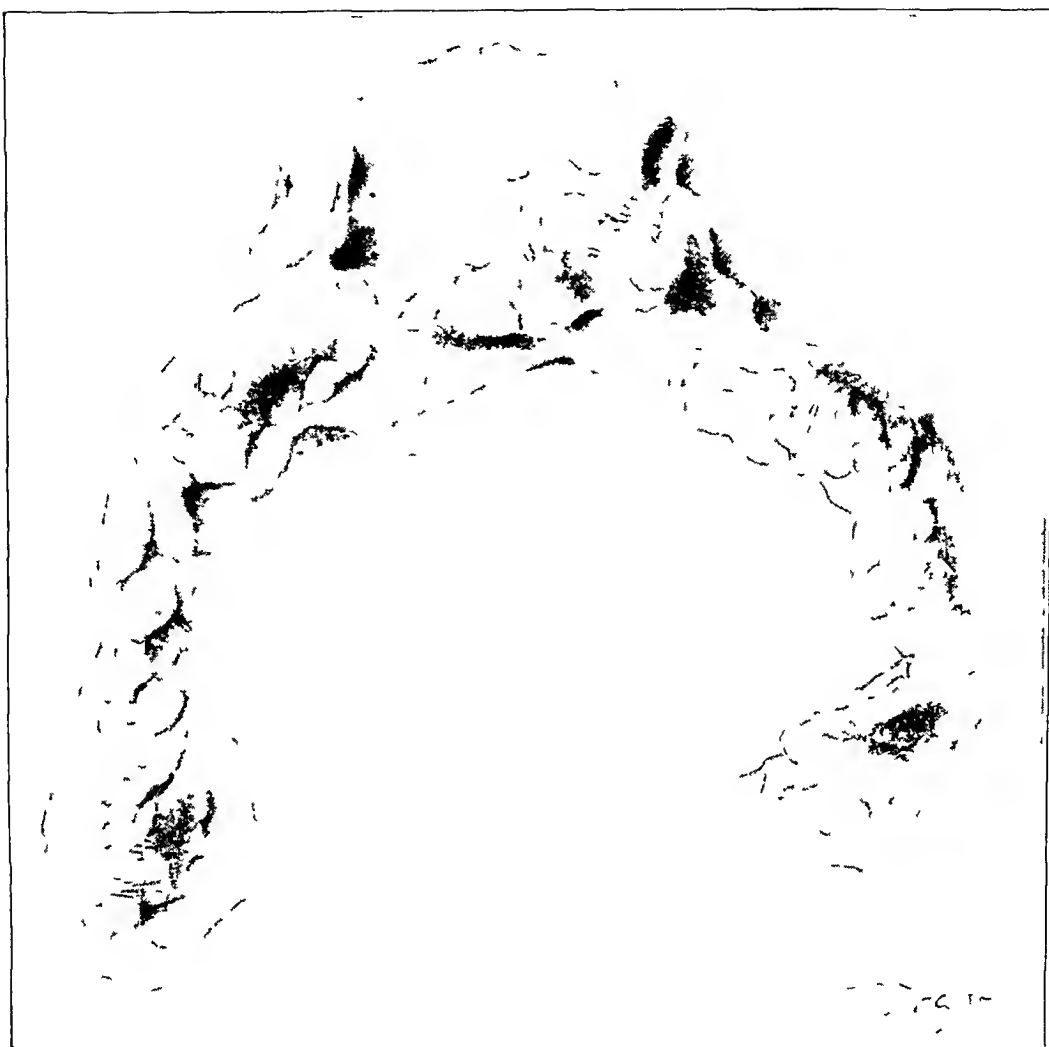


Fig 13—Pancreas after the three hour injection of 10 c c of bile into the major pancreatic duct with a pressure of 1,000 mm , showing the edema of the organ and the amber colored fluid between the lobules



observations we have made and with published data,<sup>31</sup> the following statements seem pertinent

There seems to be no doubt that the gallbladder has a contractile mechanism, exerting pressure on the contents of the biliary tract, but the contractile power of its own intrinsic muscles does not seem to be greater than the pressure that may be produced by the secretory activity of the liver. It is questionable whether the gallbladder empties itself

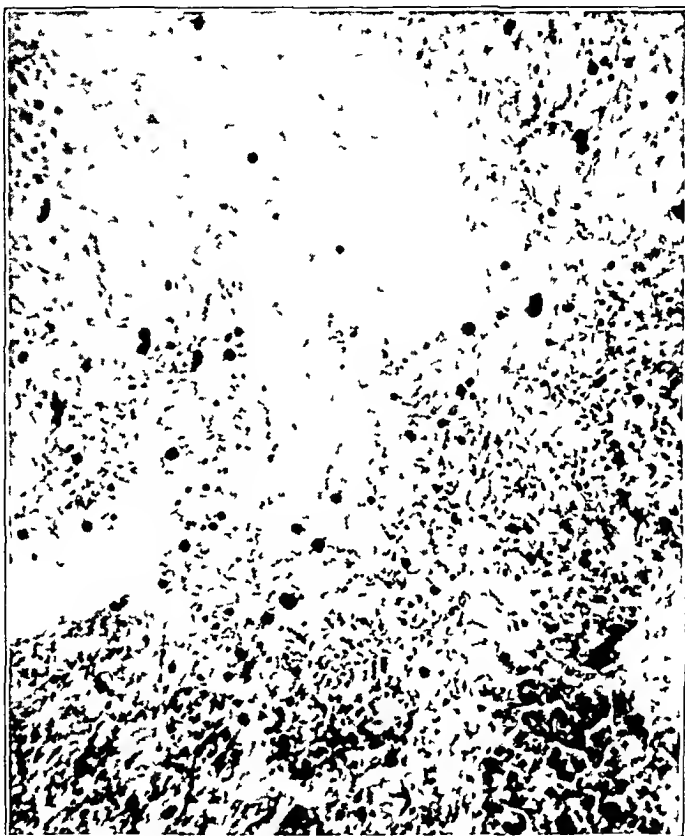


Fig 12—A higher magnification of the same section as shown in Figure 11. None of the pancreatic cells or the large coalesced masses of nuclear material appear normal,  $\times 100$

completely by contraction. So far as the maximal pressure produced in the common bile duct is concerned, the gallbladder seems of little consequence.

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31 Bainbridge, F. A., and Dale, H. H. The Contractile Mechanism of the Gallbladder and Its Extrinsic Nervous Control. *J. Physiol.* **33**: 138-155, 1905-1906. Freese, J. A. The Force of Contraction of the Gallbladder and the Course of Its Motor and Inhibitory Nerve Fibers. *Bull. Johns Hopkins Hosp.* **16**: 235-237, 1905. Lieb, C. C., and McWhorter, J. E. Action of Drugs on the Isolated Gallbladder. *J. Pharmacol. & Exper. Therap.* **7**: 83-98, 1915-1916. Okada, S. On the Contractile Movement of the Gallbladder. *J. Physiol.* **1**: 42-46, 1915.



Under the conditions of our studies, the mechanical effect of the abdominal muscles and of the diaphragm on the liver and biliary tract produced the most marked changes in the intraductal pressure. Quiet respiratory movements produced a fluctuation of pressure of 1 or 2 cm of bile. Deep respiratory movements and struggling produced a fluctuation in pressure in the common bile duct greater than that possible by the secretory pressure of the liver or by contraction of the gallbladder. If an animal is made to retch, the intraductal pressure increases enormously, reaching as high as 1,000 mm of bile. No other conditions produced a pressure as high as that which occurred during vomiting.

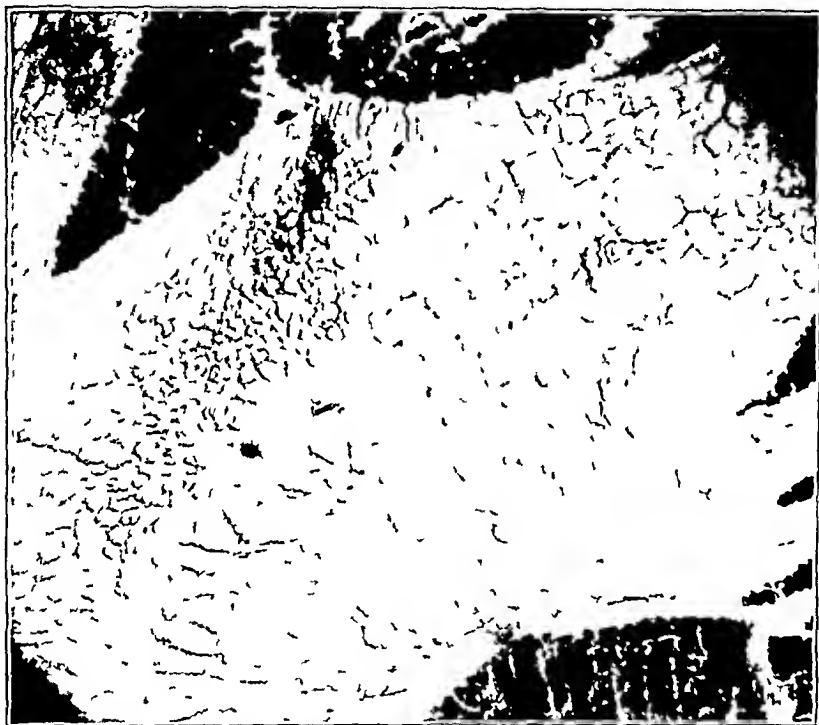


Fig 14—Photomicrograph of a section of the pancreas shown in Figure 13. The specimen of pancreas was fixed in liquor formaldehydi immediately afterward. The normal contour of the gland substance and the marked edema of the interlobular tissue may be noted,  $\times 50$ .

Whether the pressure changes in the common bile duct due to the mechanical effect of the abdominal muscles and the diaphragm have any bearing on the problem at hand is not definitely proved. If we assume as correct the usual conception that the abdominal pressure is the same throughout the peritoneal cavity and is exerted equally on all contained viscera, we may ignore the mechanically produced changes. If, however, we grant the possibility of the changes of pressure in the abdomen as affecting various organs differently, because of position, density, and other factors, the act of vomiting is of consid-

erable significance in regard to the injection of bile into the pancreatic duct. Since our present data do not clearly indicate the value to be attached to the mechanically produced changes of pressure in the common bile duct, we have studied the effect of injecting the pancreas at a pressure equal to the maximum obtained, exclusive of the mechanical agencies, and at a pressure equal to the maximum ever obtained.

We have injected sterile bile into the pancreatic duct at various pressures and studied the immediate and remote effects. Only the

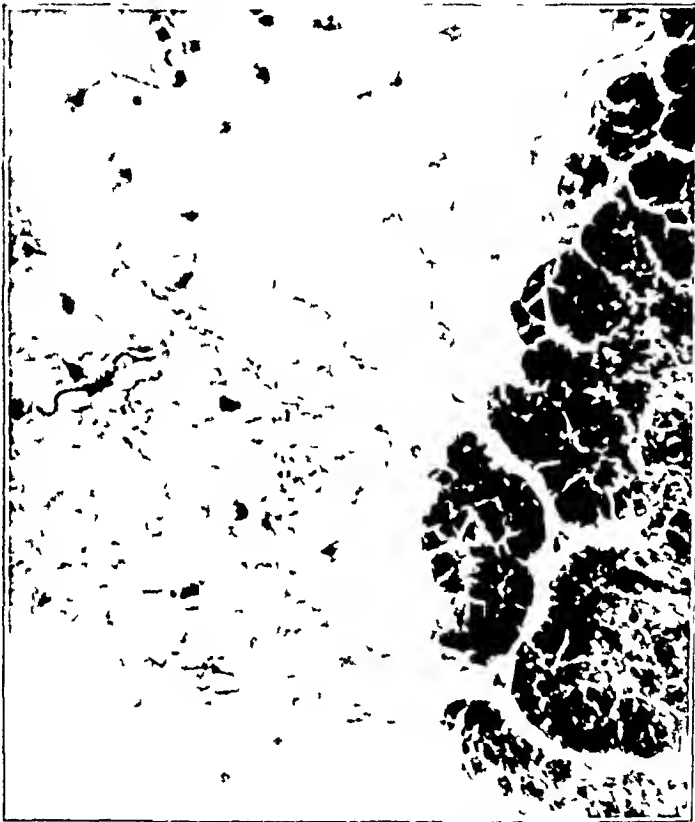


Fig 15—A higher magnification of the section shown in Figure 14. The normal appearance of the pancreatic tissue and the edema of the interlobular tissue are illustrated in detail,  $\times 100$ .

experiments in which bile was injected with a syringe and at a pressure slightly greater than that found in the common bile duct will be discussed here. The experiments were performed on dogs and cats, under ether anesthesia, and with sterile surgical technic in all experiments in which the animal was not etherized at the end of the experiment. The routine procedure was as follows:

The duodenum was exposed and the pancreatic ducts located. In some experiments the minor pancreatic duct was ligated while in others it was left intact. A cannula was placed in the major pancreatic duct

and filled with bile. If the bile was injected with a syringe, this was attached directly to the cannula and the duration of the injection was measured. If the bile was injected at a constant pressure, a bile manometer was used to determine the pressure in the common bile duct. The syringe was attached to the other arm of the T-tube, and the level of bile in the straight tube was kept constant (Fig 9 c). Care was taken to avoid the entrance of air into the duct. Usually 10 c c of bile was injected.



Fig 16—Photomicrograph of a section of the pancreas after the two and one-half hour injection of 10 c c of bile into the major pancreatic duct at a pressure of 1,200 mm. The specimen of pancreas was fixed in liquor formaldehydi immediately afterward. The marked edema in the tissue between the lobules and the leukocytic infiltration of this edematous tissue may be noted,  $\times 50$ .

If from 5 to 10 c c of bile is forced with a syringe into the pancreatic duct of a dog, the gland assumes a characteristic mottled brown appearance (Fig 10). The discoloration is most marked at the center of the lobules, little or no edema of the gland and no change in the relation of the lobules to one another result. When the gland is removed within fifteen minutes after injection, fixed, and studied

histologically, marked and characteristic changes are noted. The force of the injection produces a rupture of the smaller ducts, and bile infiltrates the lobules, hemorrhage from injured blood vessels occurs. The gland cells are swollen, many of the nuclei have disappeared or coalesced to form a large globule of nuclear material. In many areas necrosis occurs (Figs 11 and 12). If the procedure of injecting the duct has been carried out with sterile technic and the animal has been allowed to recover from the immediate effects of the operation, typical hemorrhagic pancreatitis and death follow in many instances.

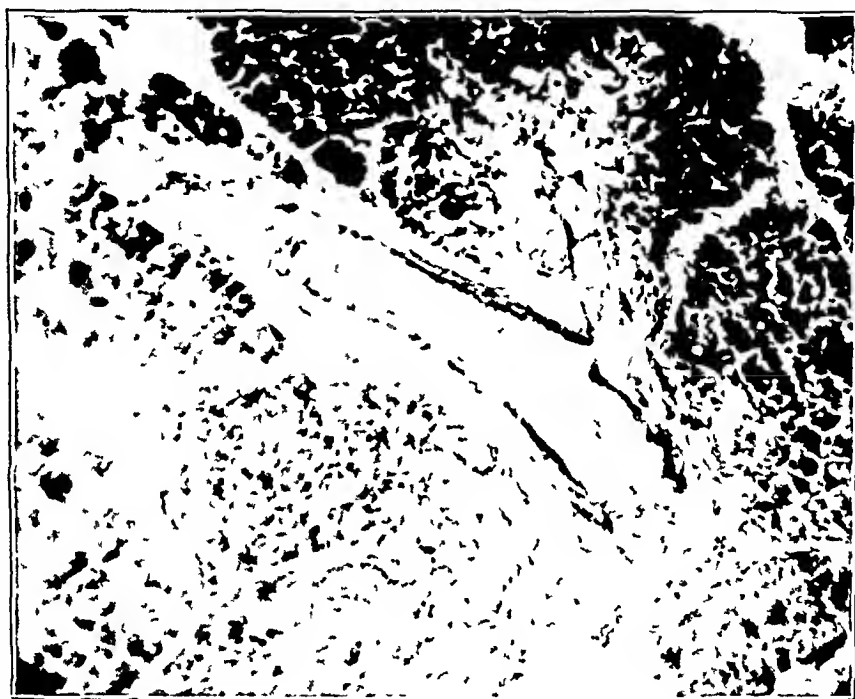


Fig 17—Higher magnification of one area showing the rupture of a small bile duct and the infiltration of the surrounding acinar tissue with bile followed by a degeneration of this tissue. This is the lowest pressure with which a rupture of the biliary ducts was produced,  $\times 100$ .

In experiments in which the bile was injected at pressures approximating those which could possibly occur in the common bile duct, several important observations were made. We were not able to inject bile into the pancreatic duct of a normal dog with a pressure less than 350 mm, in most experiments bile did not pass into the pancreatic duct at any pressure less than 500 mm. In all experiments bile passed into the pancreatic duct at a pressure less than 800 mm.

The pancreas is injected by means of a syringe in a minute or two. With low pressures the injection takes much longer. Injection of

10 c.c. of bile into the pancreatic duct at 1,000 mm. usually takes from two and one-half to three hours. When lower pressures are used more time is necessary.

The appearance of the pancreas after injection at a pressure of from 800 to 1,000 mm. is quite different from that following injection with a syringe. Grossly, the pancreas is markedly edematous. The fluid seems to pass out of the ducts into the perilobular tissue so that the lobules are spread widely apart. The fluid in the interlobular spaces is amber colored (Fig. 13). The tissues adjacent to the organ also become edematous. Microscopically, the gland tissue appears normal, but edema is observed in the interlobular tissue (Figs. 14 and 15).

In animals in which bile was injected into the pancreatic duct under sterile technic at a pressure of 1,000 mm. or less, acute pancreatitis did not occur except in one instance in which there was fat necrosis of the gland. In other words we never have produced acute pancreatitis by the injection of bile at any pressure less than 800 mm. Either these low pressures did not force bile into the pancreatic duct or if bile did pass into the duct it did not produce apparent damage and certainly not acute pancreatitis.

The difference in the results of injection of bile with a syringe and at the lower pressures seems to be due to rupture of the small pancreatic ducts and infiltration of the gland substance by bile, when the syringe is used. Mechanically this causes great damage to the gland cells and the small blood vessels, frees the pancreatic enzymes, and allows hemorrhage to occur in the gland substance. The bile itself produces changes in the gland cells. The entire process soon appears to be identical with that occurring in spontaneous acute pancreatitis. If the bile passes into the pancreas under lower pressure, less than 1,200 mm. (Figs. 16 and 17), the duct system remains intact, the bile seems to pass through the duct walls and to the interlobular spaces without seriously damaging the gland tissue (Figs. 16 and 17).

In one series of experiments, cannulas were placed in the common bile duct and in the major pancreatic duct pointing toward the respective glands. The minor pancreatic duct was ligated, and the bile manometer was interposed between the two cannulas so that the secretion from one gland could pass into the duct of the other gland and the common pressure in the two ducts could be measured. We were never able to produce sufficient pressure of bile to force it into the pancreatic duct. The intravenous injection of sodium salicylate caused the greatest pressure (300 mm. of bile), owing to the secretory activity of the liver, but this did not cause bile to pass into the pancreatic duct. On the other hand, after pancreatic secretion had been injected intravenously, pancreatic juice exceeded the flow of bile and flowed readily into the common bile duct at a pressure of less than 100 mm.

In a few experiments we estimated the secretory pressure of the pancreas in an anesthetized dog. A cannula in the major pancreatic duct was connected to the manometer previously described. The minor pancreatic duct was ligated. In order to produce the maximal pressure, the pancreas was stimulated by the injection of secretin. The pressures in these experiments varied from 260 to 350 mm, and were similar to those obtained by other investigators<sup>32</sup>. It is thus seen that the

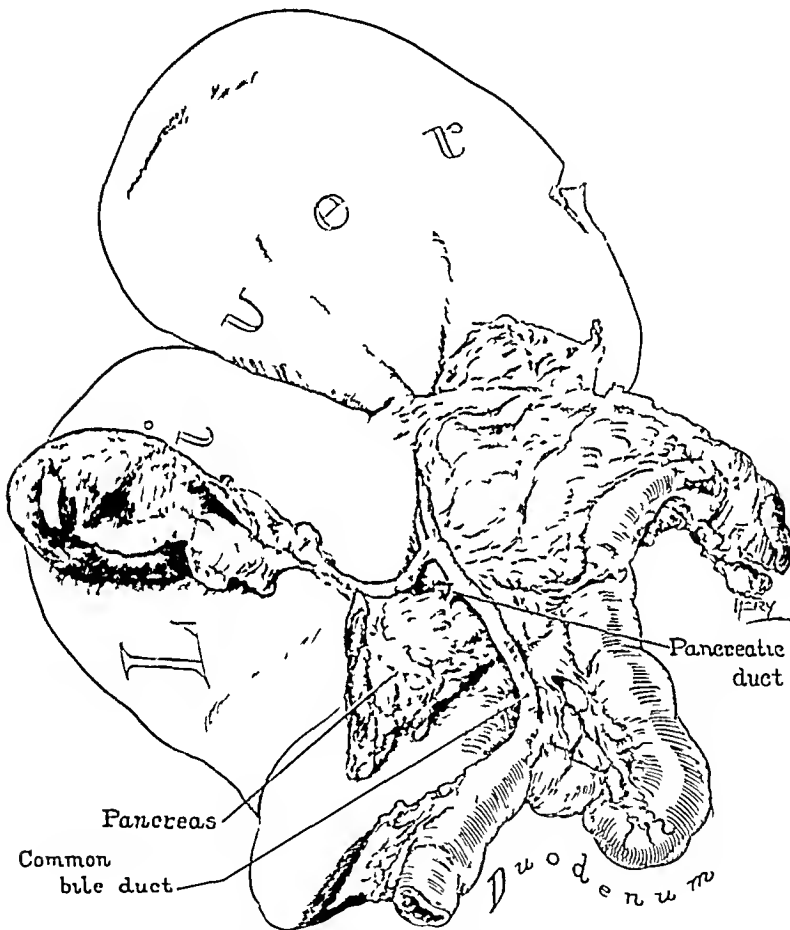


Fig 18—Biliary duct of a goat, showing the relation of the common bile duct to the pancreatic duct and duodenum. In our experiments on the goat, the common bile duct was doubly ligated and sectioned as close as possible to its entrance into the duodenal wall.

maximal secretory pressures of the liver and pancreas are about equal. Our results show that the gallbladder does not increase the pressure in the biliary tract more than that due to the secretory activity of the

<sup>32</sup> Herring, P. T., and Simpson, S. The Pressure of Pancreatic Secretion, and the Mode of Absorption of Pancreatic Juice After Obstruction of the Main Ducts of the Pancreas, *Quart J Exper Physiol* 2:99-108, 1909.

liver If the mechanical changes in intra-abdominal pressure act the same on both glands, the secretory pressures of the two glands are the only factors necessary to consider

From our experiments the conclusion that hepatitis or cirrhosis of the liver is due to a passage of pancreatic juice into the bile duct would seem almost as justifiable as that pancreatitis is due to a reflux of bile<sup>33</sup> However, there are authentic cases on record, and we have observed one, in which bile was actually in the pancreatic duct In consideration of our data this is difficult to explain, but probably it occurs by the conversion of the two ducts into one channel, owing to

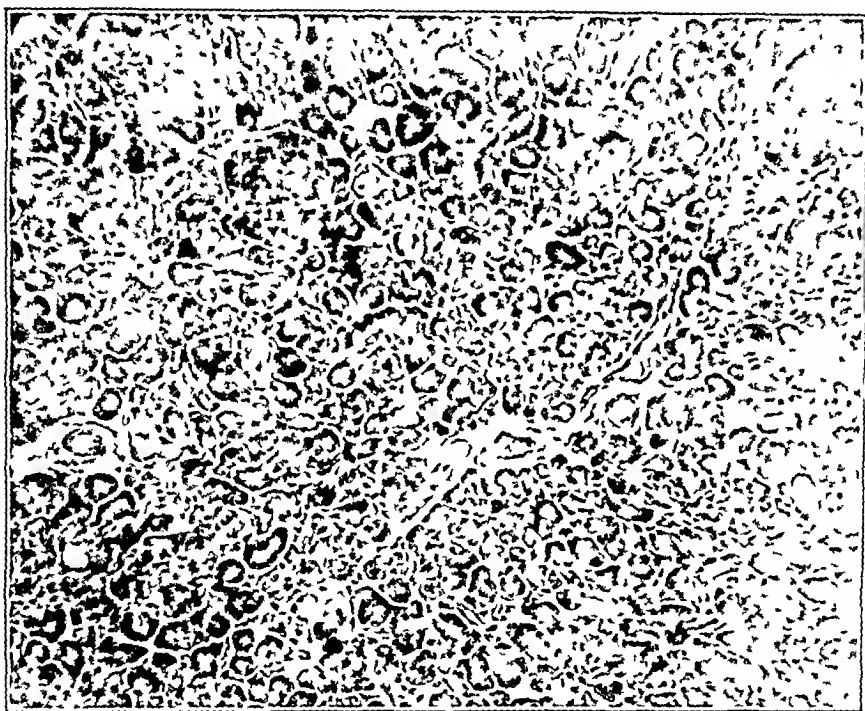


Fig 19—Photomicrograph of a section of the pancreas of a goat, taken twenty-four days after ligation of the common bile duct Grossly the pancreas was bile-stained throughout and green colored fluid escaped from the organ on the slightest abrasion of its surface On the whole the gland tissue appears normal, with no changes other than those due to obstruction of secretion

a properly situated mechanical obstruction, or, possibly, to the action of the sphincter Bile may pass slowly into the pancreatic duct for one, or all, of the following reasons The secretion of bile is continuous with changes in rate, while the secretion of the pancreatic juice is intermittent There are times when the pressure in the pancreatic duct

<sup>33</sup> Nothnagel *Encyclopedia of Practical Medicine Diseases of the Liver, Pancreas, and Suprarenal Glands*, Philadelphia, W B Saunders Company, 1903, p 642

might be considerably less than in the bile duct. The liver has firmer tissue and a stronger capsule than the pancreas. With regard to the volume of fluid secreted, the drainage of the intraductal fluid to the outside of the gland is freer in the pancreas than in the liver. While all of these factors would assist in allowing bile to pass into the pancreas, it should be noted that such a mechanism could not possibly rupture the pancreatic duct or infiltrate the gland tissue with bile outside the normal channels. If such a condition brings about pancreatitis by the injection of sterile bile, it must do so by (1) activation of the proteolytic enzyme, (2) bile acting directly on the pancreatic cells, and (3) the

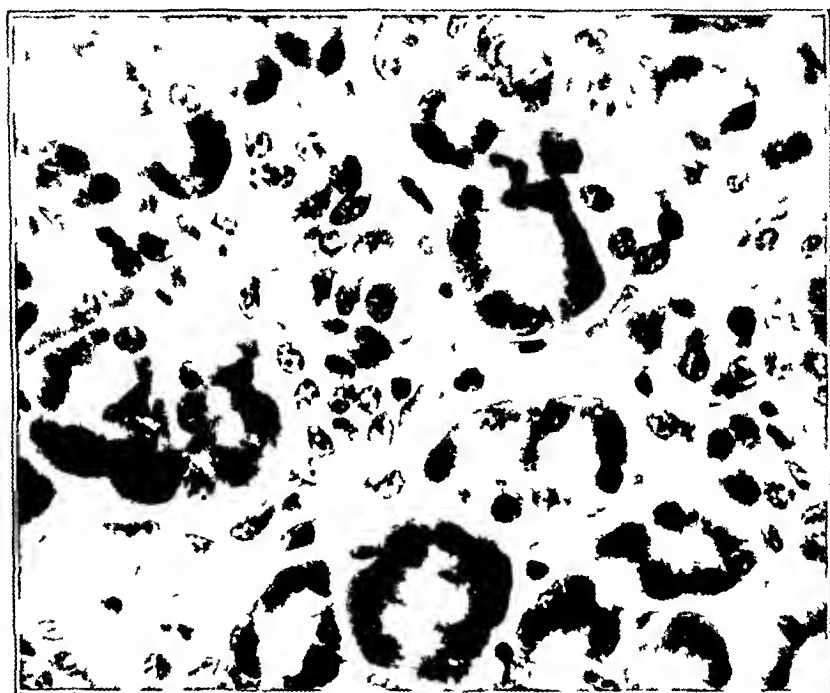


Fig 20—A higher magnification of the section shown in Figure 19. Except for the atrophy, the pancreatic tissue appears normal,  $\times 500$

washing of pancreatic enzymes out of their normal channels. It should be emphasized that we have not considered infection in this article.

In an investigation of the relationship of the pancreatic duct to the common bile duct, it was noted that each species studied could be included in one of three groups<sup>15</sup>. In one group the pancreatic duct emptied directly into the common bile duct. The anatomic arrangement of the ducts in this group seemed to offer an ideal condition for determining the existence of a physiologic mechanism which could infiltrate the pancreas with sufficient bile to produce acute pancreatitis. The goat, a readily obtainable animal with a well-developed gallbladder, and one that withstands operation well, was selected from the species that have this relationship of the ducts (Fig 18).



The operative procedures were simple. Under ether anesthesia and with sterile technic, the bile duct was exposed, doubly ligated and sectioned at its point of entrance into the duodenum. Care was taken not to injure the pancreas, but as the duct passes through the edge of the gland, trauma to the organ could not be wholly avoided. The operative wound was repaired and the animal kept under observation. The procedure was carried out in five goats. The length of life after operation varied from one to thirty days. Three of the animals died directly or indirectly from the results of the operation, one choked to death, one died from intestinal obstruction following ulceration and perforation of the gallbladder with adhesions to a loop of small intestine, and one died from a rupture of a small pancreatic duct, which



Fig 21—Photomicrograph of a section of a goat's pancreas, twenty-four hours after the injection of goat bile into the pancreatic duct with a syringe. The organ presented the characteristic appearance of acute pancreatitis that follows the injection of bile with a syringe.

permitted bile and pancreatic juice to flow into the lesser peritoneal cavity. Two lived until the effect of the occlusion of the ducts to the two glands produced such marked symptoms that they were etherized.

In the animal which died twenty-four hours after operation, the pancreas appeared normal. In one animal which died a few days after operation, no bile was noted in the pancreatic duct, while in three animals, including the two that lived the longest, the pancreatic ducts were dilated and filled with bile-stained fluid. In the

four animals that lived longer than twenty-four hours, well-marked changes, consisting of atrophy of the gland, beginning proliferation of connective tissue and, in one instance, definite intraductal infection, were noted in the pancreas. In none, however, was there, either grossly or microscopically, an area with the appearance of acute hemorrhagic pancreatitis (Figs 19 and 20). In four of the animals, small areas of fat necrosis were found, in one undoubtedly associated with the trauma of operation. In the three others, the fat necrosis occurred at a point where the pancreas and the affected fatty areas touched, and was probably associated with the obstruction of the pancreatic duct and subsequent leakage of pancreatic juice because the pancreas is quite friable in the goat.

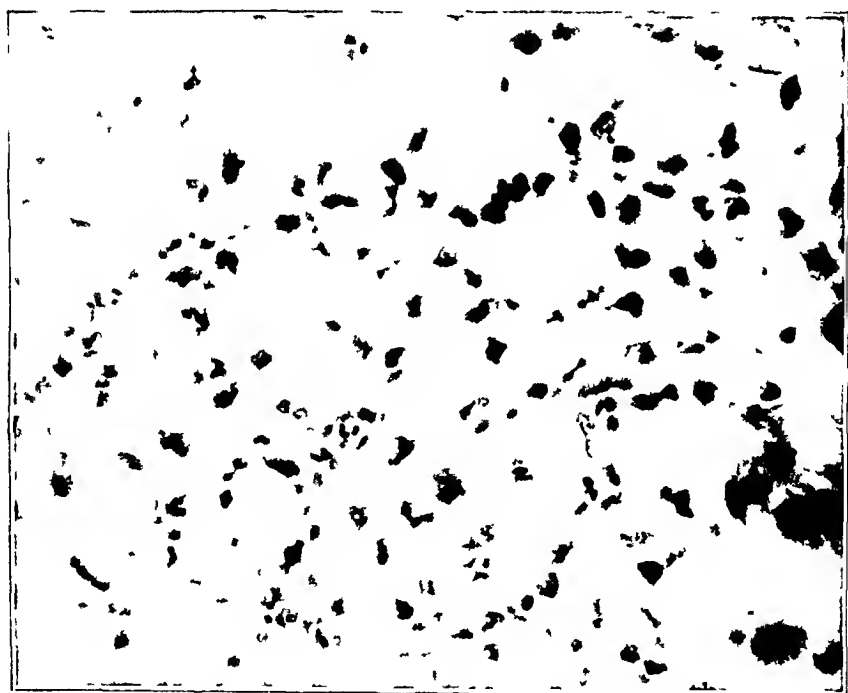


Fig 22—A higher magnification of the section shown in Figure 21. The normal arrangement of the pancreatic tissue has been destroyed. Few of the pancreatic cells remain and there is marked infiltration with leukocytes,  $\times 500$ .

The results of these experiments emphasize that (1) even with the pancreatic duct opening directly into the common bile duct and the latter completely obstructed, bile was not forced into the pancreas except after a considerable length of time, and (2) when bile did pass into the pancreatic duct and infiltrate the pancreas completely under the maximal pressure which the physiologic mechanism of the animal could produce, acute hemorrhagic pancreatitis did not follow.

It seemed essential to investigate two other points: whether acute pancreatitis would take place in goats on injection of bile into the

pancreatic duct, and whether goat bile would produce pancreatitis in other species of animals, the dog and cat. Goat bile was injected into the pancreatic duct of three goats. It was rather difficult to infiltrate the pancreas. The technic consisted of ligating the common bile duct on the gland side of the entrance of the pancreatic duct and placing a cannula in the common bile duct below the entrance of the pancreatic duct. The animal's own bile was withdrawn from the gallbladder and injected with a syringe into the pancreatic duct. In the three cases in which this was done, acute hemorrhagic pancreatitis and death occurred (Figs 21 and 22). Bile removed from the gallbladder of a goat and injected into the pancreatic duct of two dogs and one cat, 5 c c into the cat and one dog, and 10 c c into the other dog, caused the usual typical picture of hemorrhagic pancreatitis and death.

When the common bile duct is obstructed below the entrance of the pancreatic duct, it takes a long time before bile can be forced into the pancreatic duct. Eventually, however, the most minute branches of the duct are filled, but all the changes noted in the pancreas may be

TABLE 2—COMPARATIVE FIGURES GROUPED ACCORDING TO CLASSIFICATION

Author	Percentage in Groups				Specimens
	1	2	3	4	
Belou	54	30	?	?	50
Shirmer	47	?	?	?	48
Baldwin	22	13	?	1	90
Opie	11	?	?	?	160
Mann and Giordano	11	45	20	4	200

referable to obstruction of the duct and not necessarily to the presence of bile. While the pancreas showed marked changes in each instance in which the duct had been ligated longer than twenty-four hours, none other than a few small areas of fat necrosis, was in any way similar to those in acute pancreatitis. In comparing the pancreas of the goats in which bile was infiltrated into the duct by the normal physiologic mechanism with those in which it was injected with a syringe, an extraordinary difference is noted. In the latter the entire abdomen was studded with fat necrosis, the pancreas had either almost entirely disappeared or showed well marked areas characteristic of hemorrhagic pancreatitis.

During our study eleven cases of acute pancreatitis have come under our observation. We made a careful examination of the relationship of the common bile duct and the pancreatic duct and their exit into the duodenum. In none of these cases was it anatomically possible for bile to be injected into the pancreatic duct. In each instance the ducts entered the duodenum separately or the ampulla was so short that an obstruction could not have converted the two ducts into a con-

tinuous channel. Furthermore, our examination proved that in none of these cases could the sphincter have been a factor. However, we have studied one case of chronic pancreatitis in which bile was observed macroscopically throughout the duct system of the pancreas and which could have been produced as the result of sphincteric action.

#### SUMMARY

We have investigated the bile factor in pancreatitis from two chief aspects: the anatomic and the experimental.

Anatomically, two mechanisms have been suggested whereby bile can be passed into the pancreatic duct. One is based on the possibility that an obstruction could occur at the exit of the common bile duct in such a manner as to convert the two ducts into a continuous channel. We studied the relationship of the common bile duct to the pancreatic duct and their mode of entrance into the duodenum in man in order to determine the percentage of instances in which there would be an anatomic basis for the foregoing hypothesis. Our data conclusively prove that the number of instances in which the anatomic arrangement in the relationship of the two ducts would permit bile to pass into the pancreatic duct is very small. The other possibility that the sphincter at the duodenal end of the common bile duct could contract and convert the two ducts into a continuous channel has been investigated. Our data show that in most instances in man the sphincter is located at a point where contraction will close both ducts and will not convert them into a continuous channel. In a very small percentage of instances a small bundle of muscle fibers is found in a position where possibly it could convert the two ducts into a continuous channel. While there is an anatomic basis for the possibility of converting the two ducts into a continuous channel, either by mechanical obstruction or possibly by the action of a sphincter muscle, the percentage of instances in which this could occur is very small.

Experimentally, we followed three lines of investigation. (1) We estimated the possible pressure that the existing physiologic mechanism could exert in order to inject bile into the pancreatic duct, which pressure we have found to be relatively low. (2) We injected sterile bile into the pancreatic duct at the maximal pressure that could occur in the common bile duct. This did not produce typical hemorrhagic pancreatitis, although definite damage of the pancreas sometimes occurred. (3) We ligated the common bile duct in goats (a species in which the main pancreatic duct opens into the common bile duct). This did not produce acute pancreatitis.

Our investigation has proved that an anatomic and physiologic basis for the theory that reflux of bile may occur in the pancreatic duct does exist. The evidence indicates that such a reflux of bile may rarely

be the cause of chronic pancreatitis. The number of instances in which the necessary anatomic conditions are present for such an occurrence is very small. The possibility of bringing into play a physiologic mechanism which can infiltrate the pancreas with sterile bile to an extent actually to produce acute pancreatitis is questionable. Granted that the necessary anatomic, physiologic, and pathologic factors are present and that the reflux of sterile bile under such conditions does produce pancreatitis, such cause for the condition must be very rare, few cases are on record. A reflux of bile could not have been the cause in any of our cases of acute pancreatitis. It should be noted that any mechanism which will afford the possibility of bile's passing into the pancreatic duct will also obstruct the flow of pancreatic juice. Furthermore, bile has been found in the pancreatic duct without acute pancreatitis. Pathologists should, in all cases of pancreatitis, examine the relationship of the two ducts to the duodenum and to each other in order to determine whether it is anatomically possible for bile to pass into the pancreatic duct. Our data conclusively prove that we must look elsewhere for the explanation of the cause of most cases of pancreatitis.

# END-RESULTS OF FIVE HUNDRED CASES OF CHRONIC APPENDICITIS

## A STATISTICAL STUDY

JOHN B. DEEVER, M.D., AND I. S. RAVDIN, M.D.

PHILADELPHIA

The material presented in this paper is derived from a statistical and follow-up study of 500 cases of chronic appendicitis in which operation was performed by the surgical staff of the University Hospital. The cases presented are those of patients operated on during the years from 1913 to 1920. Only data which we felt were wholly reliable and complete were used, but there was no selection of cases. In order to see whether we could find any relationship between chronic appendicitis and upper abdominal disease, we have also presented some statistics from seventy-six cases of gallbladder disease and eighteen cases of gastric and duodenal ulcer. We have endeavored to approach the data with minds unprejudiced by any previous opinions.

## SEX AND AGE INCIDENCE

The series includes 260 males and 240 females. The difference between the number of males and females can be accounted for by the fact that there are nearly twice as many beds available for males as females in the surgical wards of this hospital. It would, therefore, seem that though the number is higher in the male, the actual percentage may be higher in the female. La Roque in 400 cases found a predominance of females. Maylard, in a large series of all types of appendicitis, found little difference in the sex incidence.

Table 1 shows the sex and age incidence of chronic appendicitis, and Chart I graphically represents this.

In both males and females, there is a very small number of cases in the first decade, there being but two among males and two among females. This agrees with the findings of other investigators, in that the majority of cases in the first decade are of the acute type. The rarity of the diagnosis in the first ten years of life may be due to the fact that digestive disturbances in children are so frequent and so often caused by indiscretions in diet that unless there are acute symptoms our attention is rarely directed to the appendix. It has been suggested that some of the cases of persistent vomiting may be due to a reflex from a chronically diseased appendix.

After the first decade, we find a dissimilarity in the age and sex incidence, for in the years from 10 to 20 there are forty-one males (15.7 per cent) and eighty-nine females (37.08 per cent) in our series.

This is not in accord with Maylord's series, which shows a greater number of males than females in the second decade and the reverse in the third decade. It should be remembered that Maylord included all types of appendicitis. The fact that the highest point in the female curve is reached during that period at which menstrual function is established may be significant. Several factors may play a part in this. Clinically, it is recognized that the menstrual hyperemia aggravates the condition of chronic appendicitis, for the pain often is felt more at this time or only at this time. Formerly, it was thought that women, because of the periodic pelvic hyperemia, were relatively immune to appendicitis, but the exacerbations of chronic appendicitis and the frequent onset of attacks of acute appendicitis at the time of menstruation lead one to believe that this very hyperemia may aggravate the condition in an already diseased organ.

TABLE 1—SEX AND AGE INCIDENCE OF CHRONIC APPENDICITIS

Years	Male	Female
5	0	0
5-10	2	2
10-15	12	19
15-20	29	70
20-25	86	65
25-30	47	31
30-35	31	26
35-40	21	9
40-45	14	4
45-50	5	3
50-55	5	1
55-60	1	
60-65		
65-70		2
70-75	1	
Not given	6	8
Total	260	240

The greatest number of cases in the male in our series occurs during the first half of the third decade, when the number in the female is decreasing. There were eighty-six males (33.08 per cent) and sixty-five females (22.9 per cent) during this period. From the fortieth year, we find a steady decline in the number of cases in both sexes, that of the female being more abrupt than that of the male.

Statistics concerning the symptomatology of chronic appendicitis present many difficulties. This is readily appreciated when one considers the difficulties encountered in the diagnosis because of the variability of the manifestations and the many conditions which may simulate it.

The outstanding and almost constant symptom mentioned by the patients was pain. In the majority, the pain was in the right iliac fossa.

and was periodic. Others described the pain in a variety of terms which are enumerated in Table 2. In the sixty-five patients complaining of upper abdominal pain, with or without pain in the right iliac fossa, an exploratory incision revealed no upper abdominal lesion. The next most frequent symptom was tenderness in the right iliac fossa, which was present in 367 cases. While tenderness was not a symptom in every case, abdominal pain of one sort or another was present. In a condition in which the diagnosis is frequently difficult, the symptom of pain in the right iliac fossa is extremely suggestive of a diseased appendix.

TABLE 2—FREQUENCY OF SYMPTOMS

	Cases
Pain	
Periodic in right iliac fossa	400
Constant in right iliac fossa	81
Dull in right iliac fossa	47
Cramplike in right iliac fossa	42
Burning in right iliac fossa	11
Pain in epigastrium	54
Pain in right upper quadrant	11
Pain after meals	35
Pain relieved by vomiting	7
Tenderness	369
Constipation	213
Nausea	140
Vomiting	135
Belching	96
"Indigestion"	91
Poor appetite	71
Distention	55
Sour regurgitation	53
Diarrhea	18
Jaundice	9
Vomiting blood	5
Borborygmus	4
Hiccups	2

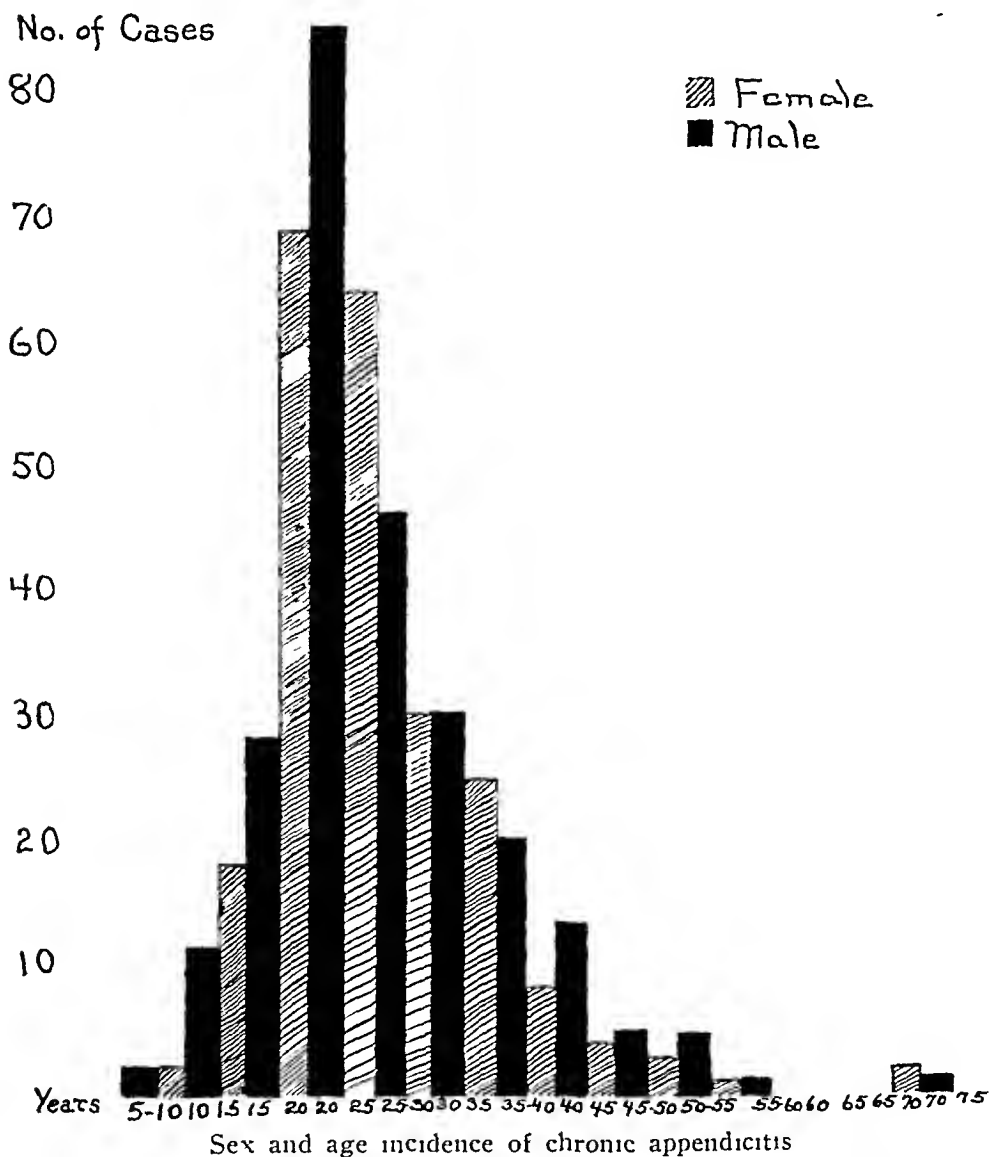
Constipation was complained of in 213 cases. Although this may be etiologic, it is a very common symptom in persons not suffering from chronic appendicitis, and from the follow-up statistics we believe that those cases presenting a picture of enteroptosis, together with constipation and a nervous instability, should not be relegated immediately to the category of those suffering from chronic appendicitis. Constipation and chronic appendicitis are so frequently associated that it is difficult to determine which condition is the cause and which the effect.

Nausea, vomiting, belching and other gastric manifestations were very frequent. In the five cases in which there was hematemesis and in the thirty-five with pain in relation to the ingestion of food, no upper abdominal lesions were demonstrable at operation.

Since our interpretation of a chronically diseased appendix clinically, is that of an appendix subjected to recurrent inflammation the



history of attacks of pain in the abdomen which might have been due to appendicitis is of great importance. The total number of patients giving a definite history of previous attacks of pain is 418. In those histories in which the number of previous attacks of pain are recorded, thirty-two patients had had one attack, sixty-three had had two attacks, and 112, three or more attacks, previously. Fourteen patients complained of attacks of pain over a period of ten years, fifty-two stated



the first attack had occurred from five to ten years before and 235 from one to five years, while only eighty-three had their first attack less than a year before admission.

It is significant that 145 patients who gave a history of long chronicity had an acute exacerbation necessitating immediate operation. The importance of this will be seen later in discussing mortality.

As will be noted, in eighty-two cases in this series no history of a previous acute attack could be elicited, these patients complained of a constant dull or burning pain in the right iliac fossa. This would suggest that a chronic process may be progressing without acute symptoms.

#### OPERATIVE FINDINGS AND PATHOLOGY

In 160 of the cases, adhesions binding down the appendix were noted. This number undoubtedly does not include those cases in which adhesions of a minor character were observed. The appendix was retrocecal in sixty-seven cases. Fecal concretions were found in twenty-two cases (4.4 per cent). This figure is low, since the statistics usually show from 15 to 20 per cent of the cases of appendicitis having fecal concretions.

In eight of the cases, tubo-ovarian pathology, exclusive of that of gonorrheal origin, was present. It is impossible to determine whether the initial pathologic condition was in the appendix or in the pelvic organs.

TABLE 3—PATHOLOGIC FINDINGS IN PATIENTS OPERATED ON AS CHRONIC CASES

Lesions	Cases
Chronic catarrhal or diffuse	113
Chronic interstitial	106
Chronic obliterative	68
Chronic ulcerative	29
Chronic periappendicitis	11
Chronic tuberculous	6
Carcinoma	1
Mucocele	2
Normal	19
Total	355

Clado's appendiculo-ovarian ligament contains lymphatics which pass to the broad ligament, the pelvic connective tissue and the internal iliac glands, and in this way it is conceivable that appendicular disease may be transferred to the pelvis, as well as by direct proximity of the organs. Williams and Slater quote Waegili as believing the appendix secondarily involved in 16.4 per cent of 896 gynecologic laparotomies.

Table 3 illustrates the pathologic findings in the patients operated on during the chronic stage. In the reports returned to the surgeons, twenty-seven different terms were used to describe the chronic lesions. We have grouped these in Table 3. A plea might well be made for a simpler and more uniform classification by pathologists.

Table 4 gives the pathologic condition of the patients operated on during an acute or subacute exacerbation but who gave a definite history of chronicity.

The majority of the pathologic reports of these 145 cases show an acute process superimposed on a chronic one. Thus, in considering the chronically inflamed appendix from the point of view of pathology, we have several types to consider. First, the appendix which shows an almost healed inflammatory lesion, but which at some previous time has gone through an acute or subacute process, second, the chronically inflamed appendix which has not begun with an acute or subacute reaction, but which shows chronic changes and which may have given rise to no symptoms, and third, either of the previous types which, by their tissue changes, have prepared the soil for an acute exacerbation.

TABLE 4—PATHOLOGIC FINDINGS IN PATIENTS OPERATED ON DURING AN ACUTE ATTACK, BUT WITH HISTORY OF CHRONICITY

Condition	Cases
Chronic diffuse or catarrhal	
and acute catarrhal	35
and subacute catarrhal	3
and acute periappendicitis	3
and acute ulcerative	1
and acute gangrenous	1
and acute suppurative	1
/	
Chronic interstitial	
and acute ulcerative	19
and acute interstitial	23
and acute catarrhal	14
Chronic obliterative	
and acute catarrhal	4
and acute suppurative	2
and acute interstitial	1
Chronic ulcerative	
and acute ulcerative	3
and acute gangrenous	1
Acute interstitial	11
Acute ulcerative	11
Acute suppurative and gangrenous	8
Acute suppurative	2
Acute diffuse	1
Acute ulcerative and tuberculous	1
Total	145

An attempt to classify the symptoms of the cases on a pathologic basis was found to be useless except as to the three general groups given above. We found a similar symptomatology in all the cases of chronic appendicitis, including those of tuberculosis and carcinoma of the appendix, so that no common pathologic finding can be suggested in connection with any group of clinical symptoms.

The pathologic reports in a series of 1,000 appendectomies performed during the quiescent period by Battle agree fairly well with our statistics, with the exception that he did not encounter so many cases of tuberculosis.

In three of the cases, *Oryzias vermicularis* was found in the appendix. Whether these were causal or simply coincident it is impossible to state.

#### MORTALITY

Among the 355 patients operated on during the quiescent period, there was one death (0.27 per cent). This death followed an intestinal obstruction which was secondary to a congenital fold of peritoneum, discovered at operation.

Of the 145 cases in which operation was performed during an acute exacerbation, eleven cases were perforated, and there were four deaths (2.7 per cent).

La Roque in 600 cases of appendicitis of all types had four deaths (0.66 per cent), and Battle in 1,000 cases of chronic appendicitis had two deaths (0.2 per cent). Gibson had four deaths in 555 cases of chronic appendicitis (0.72 per cent).

#### RELATION TO UPPER ABDOMINAL DISEASE

Chronic appendicitis and upper abdominal disease are so frequently associated that many surgeons do not think it justifiable to remove a chronically diseased appendix without exploring the upper abdomen and vice versa. Upper abdominal lesions, such as gallbladder disease and gastric and duodenal ulcer, should not be remedied without removing the appendix.

It was with a view of determining whether or not there was a relationship between disease of the appendix and of these organs that we have examined the records of seventy-six cases of gallbladder disease and eighteen cases of gastric and duodenal ulcer in which the appendix was removed at the operation for the upper abdominal disease. Of the seventy-six cases of gallbladder disease, in forty-four there was a history which pointed to previous appendiceal pathology, sixty-nine (90 per cent) of the appendixes removed showing definite appendiceal pathology, the pathologic reports being in no wise different from the reports of the chronic cases already given. There was one case in which the appendix incidentally removed proved to be an adenocarcinoma. Of the eighteen cases of gastric and duodenal ulcer, in nine there was a previous history of appendicitis and eleven (61 per cent) of the appendixes showed chronic pathologic changes.

It is interesting to compare the age incidence of the cases of chronic appendicitis and those of upper abdominal disease. It was found that the upper abdominal cases occur later in life than those of chronic

appendicitis, and it is possible that the diseased appendix may have played some etiologic part in the upper abdominal disease

Heyd found the appendix diseased in 67 per cent of the cases in which cholecystectomy was performed and in 54 and 66 per cent, respectively, of the cases in which operation was performed for gastric and duodenal ulcers. He says that "in 15 per cent of all laparotomies there are two lesions sufficiently severe to warrant operation." Dubard found chronic appendicitis in more than 33 per cent of 145 cases of ulcer, and explained some of the failures after gastro-enterostomy as due to operation on the one organ.

It is true, however, as we have already shown in our analysis of symptoms, that chronic appendicitis may simulate disease in the upper abdomen. In Barclay and McWilliams' series of 200 patients, 49 per cent had pain with stomach symptoms and 80 per cent of these were cured by appendectomy. Five of our cases, four of Heyd's and fifteen of Bassler's in which hematemesis was a symptom revealed no ulcer at an exploratory laparotomy and every case was relieved by appendectomy. Bassler explains this as a toxic effect of chronic appendicitis. Sir Berkeley Moynihan's statement that most of the ulcers of the stomach are situated in the right iliac fossa has its origin in facts similar to these.

#### FOLLOW-UP DATA

This material is based on the replies to the following questions

- 1 How long were you incapacitated for work following operation?
- 2 Were the symptoms for which the operation was performed relieved?
- 3 If not, what symptoms still persist?
- 4 Have you had any further operation for these symptoms?

The follow-up was carried out either by personal interview and examination of the patient or by mail. In all, 226 patients were heard from. Gibson has suggested that the end-results might be more valuable if every case could be followed up, since many patients wholly relieved may ignore communications. We have however, presented the statistics as we have them. It is the only method of determining whether or not we accuse the appendix without sufficient evidence. It should also be borne in mind that these patients were operated on in a teaching hospital and that many of them, especially the obscure cases, were studied primarily in the medical wards. It may thus seem to some observers that the results are better than those usually reported.

The first question was asked in order to ascertain whether the statement so frequently made to patients that they "can return to work in ten to twelve days" is correct. We found that, while an occasional

patient was able to work two weeks after operation, one patient was incapacitated for thirty-two weeks. This patient was similar to one of Gibson's cases in that he developed a fecal fistula after operation. The average time before the patient was able to go to work was five and seventy-three hundredths weeks. Thus the question of diagnosis becomes doubly important since the patient or his dependents may suffer economically.

The answers to the second question are not entirely gratifying. One hundred and eighty-eight patients were entirely relieved of their symptoms, twenty-two were partially relieved, and sixteen were unimproved or made worse.

Thus our figures are (1) complete relief of symptoms by operation, 83.1 per cent, (2) partial relief of symptoms by operation, 9.7 per cent, and (3) no relief of symptoms by operation, 7.07 per cent.

TABLE 5—COMPLAINTS OF PATIENTS WHO WERE PARTIALLY RELIEVED OF SYMPTOMS

Complaints	Cases
Constipation	6
Gynecologic conditions (prolapsus, partial)	1
Occasional pain in scar	3
Diarrhea	1
Soreness in right iliac fossa	3
Tuberculous orchitis	1
Slight indigestion	2
Backache	1

The answers to question 3 throw some light on the preceding figures. We have grouped the complaints of the patients as to whether they were partially relieved or not.

*Partially Relieved*—These patients have minor complaints but were relieved of the principal symptoms (Table 5).

It will be seen that the major complaint in the 9.7 per cent of patients who were only partially relieved was constipation. Five of these patients had McBurney incisions.

*Unrelieved*—This group comprises cases in some of which, at least, in our series, an incorrect diagnosis was made.

1. This patient was operated on two years later for gallstones and has since been well.

2. This patient was operated on later for floating kidney and since then has had relief of symptoms.

3. This patient was operated on later and a duodenal ulcer was found.

4. This patient has been operated on twice since appendectomy for adhesions.

5 This patient was operated on, the case being diagnosed, on later admission, as gastric neurosis

6 This patient has a hernia following a fecal fistula

Thus mistakes were made in not finding the cholelithiasis, the floating kidney, and the duodenal ulcer. It was also a mistake to operate in the case of gastric neurosis. Whether the adhesions were due to the original infection causing the appendicitis or whether they were post-operative we cannot say.

#### CONCLUSIONS

1 Few cases of chronic appendicitis are observed in the first decade

2 There is a variation of sex and age incidence in the second and third decades

3 The most frequent symptom is periodic pain in the right iliac fossa, and in a patient carefully studied this symptom is suggestive

4 A normal appendix was removed in 38 per cent of our cases

5 The symptoms of the seven cases of tuberculous appendicitis and one of carcinoma did not differ in any way from the remaining cases in our series

6 The mortality of the cases in which operation was performed during the quiescent period was 0.27 per cent, while in those in which operation was performed during the acute stage it was 2.7 per cent

7 There seems to be a definite relation between appendicitis and upper abdominal disease and between appendicitis and pelvic disease

8 Hematemesis may be a manifestation of chronic appendicitis

9 The average postoperative incapacitation was five and seventy-three hundredths weeks

10 Eighty-three and one-tenth per cent of the patients followed up were entirely relieved, 9.7 per cent were partially relieved and 7.07 per cent were unrelieved

11 The latter group was partly due to pathologic conditions unrecognized because of faulty study and exploration

# STUDIES IN EXPERIMENTAL TRAUMATIC SHOCK

## VI THE ACTION OF ETHER ON THE CIRCULATION IN TRAUMATIC SHOCK \*

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This study was undertaken in an attempt to determine the effects of ether on the factors which influence the blood pressure, with special reference to the conditions as they occur in shock or circulatory failure. The fact, long known, that a patient in a condition of shock is a poor anesthetic risk was strongly brought to the attention of surgeons during the recent war, and led to an experimental study of the problem at the Laboratory for Surgical Research, A E F, under the direction of Lieut-Col W B Cannon. This study has been continued in the Laboratory of Physiology at the Harvard Medical School.

In the account which follows, the effects of ether on the blood pressure will be first considered, then an examination of its action on the heart, vasomotor system and blood vessels, and finally a discussion from the point of view of the circulation as a whole, together with a consideration of the changes occurring in shock.

### THE EFFECTS OF ETHER ON THE BLOOD PRESSURE

The interpretation of blood pressure changes produced by ether is extremely difficult. Alterations may be produced by direct action on the heart or blood vessels or indirectly through the vasomotor or vagus centers, and by reflex effects from many parts of the body, or by various combinations of these factors. Moreover, the depressant action of the narcotic on the general body functions, such as changes in muscle tone or cell metabolism, may cause, independently of any direct action on the circulatory system, a secondary modification of the blood pressure. Partial asphyxia, produced by a reduction of the oxygen in the inspired air, by a depression of the respiration, or by the effects of a fall in blood pressure, may also be a contributory cause to any pressure changes. It is, therefore, not surprising to find reported in the literature a diversity of effects from the administration of ether, and much difference of opinion as to their cause. It is only by a study of the influence of the anesthetic on the separate parts of the circulation that significant conclusions can be reached, nevertheless, the form of the blood pressure curve, under various conditions of ether administration and under varying conditions of the patient or animal, shows instructive differences.

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\* From the Laboratories of Physiology of the Harvard Medical School



*Literature*—In recent years, there has appeared in the literature a large number of clinical observations on the effects of anesthetics on the blood pressure. It will be sufficient to mention here only a few of the most important papers, since the experimental work performed on animals gives us more reliable information. Most of the earlier measurements of blood pressure in man under anesthetics were made for a comparison of the effects of ether and chloroform, and it is now well established that the administration of chloroform results in a definite decrease in the blood pressure. The effect of ether is not so clear. The earliest direct measurements of blood pressure in man during ether anesthesia were made by Blauel.<sup>1</sup> In a series of 100 patients, a large percentage showed a rise in blood pressure, and it was only at the end of the operation that there was any tendency to a fall. The observations of Kaefer,<sup>2</sup> Holz,<sup>3</sup> Mummery,<sup>4</sup> Walton,<sup>5</sup> Blumfeld,<sup>6</sup> Fairlee,<sup>7</sup> and Marshall,<sup>8</sup> show that there is either a slight rise in pressure during the administration of ether or no change. McWilliam<sup>9</sup> reports that ether administration results in a gradual but slight fall in pressure. The observations of Cook and Briggs<sup>10</sup> indicate that ether causes a transitory initial rise followed by a slight fall in pressure. Similar conclusions are reached by Cushny<sup>11</sup> (p. 205).

While it appears to be generally recognized that patients in a condition of shock or circulatory collapse are very susceptible to the effects of ether and chloroform, no observations on the blood pressure changes resulting under these conditions have been found in the literature. Marshall,<sup>8</sup> working with the severely wounded at the front, found that, after ether anesthesia, collapse frequently occurred, while under nitrous-oxid and oxygen there was but slight reduction in the blood pressure. In addition, there are a considerable number of clinical observations showing the superiority of nitrous oxid anesthesia over that of ether in conditions of shock, and these testify to the sensitive condition of the

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1 Blauel. Beitr. z. klin. Chir. **31** 271, 1901.

2 Kaefer. St. Petersburg med. Wchnschr. **10** 233, 1893, referred to in Zentralbl. f. Chir. **21** 58, 1894.

3 Holz. Beitr. z. klin. Chir. **97** 177, 1915.

4 Mummery. Lancet **1** 696, 776, 846, 1905.

5 Walton. Lancet **2** 17, 1905.

6 Blumfeld. Practitioner, Jan.-June, 1909, p. 231.

7 Fairlee. Lancet **1** 603, 1914.

8 Marshall. Proc. Roy. Soc. Med., Sect. on Anesthetics **10** 17, 1916-1917.

9 McWilliam, referred to in Patton. Anaesthesia and Anaesthetics, Ed. 2, Chicago, Cleveland Press, 1906, p. 100.

10 Cook and Briggs. Bull. Johns Hopkins Hosp. **11** 451, 1903.

11 Cushny. Text Book of Pharmacology and Therapeutics, Ed. 7, Philadelphia, Lea & Fabiger, 1918.

circulatory system to the administration of ether Cannon<sup>12</sup> reports a series of observations on the blood pressure and alkali reserve in severely wounded men, under ether, before and after operation. It was found that the blood pressure fell during operation and that, in general the greater the fall in blood pressure the lower the original carbon dioxide capacity of the blood. This observation is of interest in connection with experimental work<sup>13</sup> showing that the degree of acidosis is a direct indication of the circulatory condition, i. e., the extent of shock.

To summarize, the evidence indicates that ether, properly administered to normal subjects, produces no fall in blood pressure or may even cause a transitory increase during the early stages of its administration, while in shock, circulatory collapse frequently occurs.

It is a matter of common experience in the physiologic laboratory that animals may be kept under ether anesthesia for a number of hours without any appreciable drop in blood pressure. Knoll,<sup>14</sup> in 1878, reported a fall in pressure from ether and chloroform in rabbits. Similar observations were made by Cushny<sup>15</sup> in rabbits and dogs, by Witte<sup>16</sup> in rabbits, by Pick<sup>17</sup> in dogs, and McWilliam<sup>18</sup> in cats. Kionka<sup>19</sup> and Elfstrand<sup>20</sup> found practically no change in the blood pressure in rabbits under ether anesthesia. Similar conclusions were reached by Bock<sup>21</sup> from a series of experiments on isolated heart-lung preparations from rabbits. Csiky<sup>22</sup> reports, from experiments on dogs, that ether raises the blood pressure by stimulation of the heart. Duplay and Hallion<sup>23</sup> made a careful study of the fluctuations of blood pressure occurring under chloroform and ether anesthesia, and an attempt was made to determine the cause of these variations by simultaneous measurements of the changes in volume of the kidney. The conclusion was reached that the first rise in the blood pressure curve was due to vasoconstriction, while the fall in pressure which followed was due to a decrease in the

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12 Cannon, W. B. Acidosis in Shock, Hemorrhage and Gas Infection, *J. A. M. A.* **70** 531 (Feb. 23) 1918.

13 Cannon, W. B., and Cattell, McKee. Studies in Experimental Traumatic Shock. V. The Critical Level in a Falling Blood Pressure, *Arch. Surg.* **4** 300 (March) 1922.

14 Knoll. Philipp. Sitzungsberichte der Akademie der Wissenschaften, Math.-Naturw. Cl., Wien **78** 223, 1878.

15 Cushny. *Ztschr. f. Biol.* **28** 365, 1891.

16 Witte. Dissert. Göttingen, 1898.

17 Pick. *Arch. f. exper. Path. u. Pharmacol.* **42** 399, 1899.

18 McWilliam. *Brit. M. J.* **2** 831, 890, 948, 1890.

19 Kionka. *Arch. f. klin. Chir.* **1** 339, 1895.

20 Elfstrand. *Arch. f. Path. u. Pharmacol.* **43** 435, 1900.

21 Bock. *Arch. f. exper. Path. u. Pharmacol.* **41** 173, 1899.

22 Csiky. *Magy. droosi Arch.* **7**.

23 Duplay and Hallion. *Arch. gen. de med.* **9** 130, 1900.

activity of the heart Cushny, in an early edition of his textbook,<sup>24</sup> states that the evidence indicates that the first effect of ether is a depression of the heart, resulting in a fall in blood pressure, which in some instances may be compensated for by a vasoconstriction from reflex stimulation of the vasomotor center, so that the blood pressure may rise while the heart is slowed The statement is made in a report of the Medical Research Committee of Great Britain<sup>25</sup> that experiments with animals under ether anesthesia have shown that, when a state of acidosis has been produced, the administration of ether in but slight excess of the amount needed to maintain anesthesia readily induces a fall in blood pressure Other than this, no reference has been found bearing on the question of the effect of ether in experimental shock

It will be noted that there is a slight discrepancy in the conclusions reached by different observers, a few reporting no change in blood pressure under ether anesthesia but the majority finding some fall In the light of research on the action of ether on the separate parts of the circulatory system, this is not surprising, the blood pressure being dependent on the summation of a number of factors, some of which tend to increase it and others to have the opposite effect Moreover, there is the factor of individual variation, perhaps dependent to a considerable extent on the condition of the animal Any one who has worked on the vasomotor reactions is aware how great these variations may be The method and rate of administration have an important influence on the result These factors alone in certain individual animals will determine whether the net result is a fall or a rise in blood pressure

*Method*—Following is a general outline of the technic employed in obtaining the blood pressure records In addition, there were several special methods used and modifications of procedure, which will be described in connection with the particular experiment in which they were employed In all the later experiments, cats were used, while many of the earlier ones, which were done at Dijon, France, were performed on dogs and rabbits Various anesthetics were used, depending on the point to be investigated Usually, it was found most convenient and satisfactory to keep the animals under light ether anesthesia, which could be entirely removed just before making a test to determine the effects on the blood pressure of inspiring strong ether In other cases, ethyl carbamate (urethane) was used, and, in still others, the cats were decerebrated under preliminary ether anesthesia

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<sup>24</sup> Cushny Text Book of Pharmacology and Therapeutics, Ed 6, 1915, p 201

<sup>25</sup> Medical Research Committee Report of Special Investigative Committee on Surgical Shock, No 7 Acidosis and Shock, 1918, p 12

Blood pressure records were obtained from the carotid artery of the animal by means of an ordinary mercury manometer and kymograph. Usually, the drum was run at a slow rate, so that pressure changes covering relatively long periods might be conveniently recorded, but in other cases, when changes in the heart rate were to be determined, a more rapid rate was employed. Various methods of ether administration were used at different stages of the experiments. The following was found to be the most satisfactory. A constant stream of air, from a source of pressure, was passed through an ether bottle provided with a short-circuiting arrangement, so that all, part, or none of the air bubbled through the ether. This was conducted by means of rubber tubing to the animal through a T-shaped cannula in the trachea, the other end of which was connected to a Muller water valve. Usually, the animal was allowed to breathe naturally, but a motor-driven interrupter of the air current was placed between the source of compressed air and the ether bottle so that in case artificial respiration was desired it was readily available. The advantage of this method is that the ether can be administered without rebreathing, and without in any way disturbing the animal, all the other conditions remaining constant. The concentration of the ether in the inspired air was not measured, but the conditions in the whole series of experiments were practically uniform and there is no reason to suppose that there was wide variation in the ether concentrations. In any case, small variations would not interfere with the comparisons, as the depth of anesthesia, as indicated by the disappearance of reflexes, was used as a standard, and this probably corresponds closely to the concentration of ether in the blood, regardless of the slight differences of concentration in the inspired air. While the ether was being given during a test, repeated observations were made on the eye reflex by a gentle and uniform tap at the inner corner of the eyelids and, at the time when the reflex had just disappeared, the blood pressure noted. Thus it was possible to make comparisons of the blood pressures at a given depth of anesthesia in different animals, and in the same animal under different conditions. In making a test, the ether was turned on suddenly and was of such strength that it would cause a fairly rapid disappearance of the reflexes, and, if continued long enough, would cause death. It having been abundantly demonstrated that a condition of light anesthesia could be brought about with practically no effect on the blood pressure of the normal animal, the object of these experiments was to study not the effects of light anesthesia but rather the acute effects of concentrations of ether having a definite influence on the blood pressure. In most of the experiments, the administration of ether was continued nearly to the point where the life of the animal was endangered. A note was made on the blood pressure record at the instant the eye reflex could no longer be obtained,

and also at the point where, after a given period of time, the ether was discontinued

In nearly all cases, observations were made on the effect of ether on the blood pressure early in the experiment, when the animal was in good condition, and again later, after the development of shock, all conditions being kept as nearly uniform as possible throughout the

ANALYSIS OF BLOOD PRESSURE CHANGES FROM ETHER IN A SERIES OF TWENTY CATS ANESTHETIZED UNTIL THE EYE REFLEX DISAPPEARED

Primary Drop in Pressure Followed by a Rise (12 Cases)

Experiment	Blood Pressure		
	At Start	Fell to	As Reflex Disappeared Rose to
48	120	100	156
49	125	90	122
51	160	135	175
52	145	90	120
56	115	80	110
57	98	45	100
59b	115	88	115
68	70	48	84
69	120	90	115
70	140	125	145
71	110	80	100
72	135	125	130
Average	122	91	123

No Rise Following Primary Drop in Blood Pressure (5 Cases)

Experiment	Blood Pressure	
	At Start	Fell to and Remained at
53	118	75
60	126	126
64	155	135
65	145	130
67	125	115
Average	134	116

Primary Drop in Blood Pressure Followed by Further Fall (3 Cases)

Experiment	Blood Pressure	
	At Start	Comment
50	132	Rapid fall toward zero
58	115	Rapid fall toward zero
66	165	Rapid fall toward zero

experiment In many cases, the animal spontaneously developed a condition typical of shock after having been kept anesthetized for a number of hours, in others, the condition was artificially hastened by interference with the circulation This was done by a method, previously described,<sup>13</sup> by which the intrapericardial pressure is increased, thus interfering with the normal return of the blood to the heart and reducing the blood pressure The reduction of the pressure to 60 mm of mercury for one hour was usually sufficient to produce symptoms of shock

*The Effect of Ether on the Blood Pressure of Normal Cats*—Almost invariably there is a sharp primary fall in blood pressure at the beginning of the ether administration, which, in the majority of cases, is temporary and is followed by a gradual recovery as the anesthesia deepens This rise may reach a greater height than the original blood

pressure or it may remain somewhat below this level. In a series of twenty experiments on cats, summarized in the accompanying table, this type of reaction occurred in 60 per cent of the cases. A somewhat extreme example is illustrated by the record presented in Figure 1 *a*. In these cases, the average drop in blood pressure was 32 mm of mercury. This drop, however, is temporary, the pressure being back to normal by the time a degree of anesthesia was reached sufficient to cause a disappearance of the eye reflex. This degree of anesthesia was

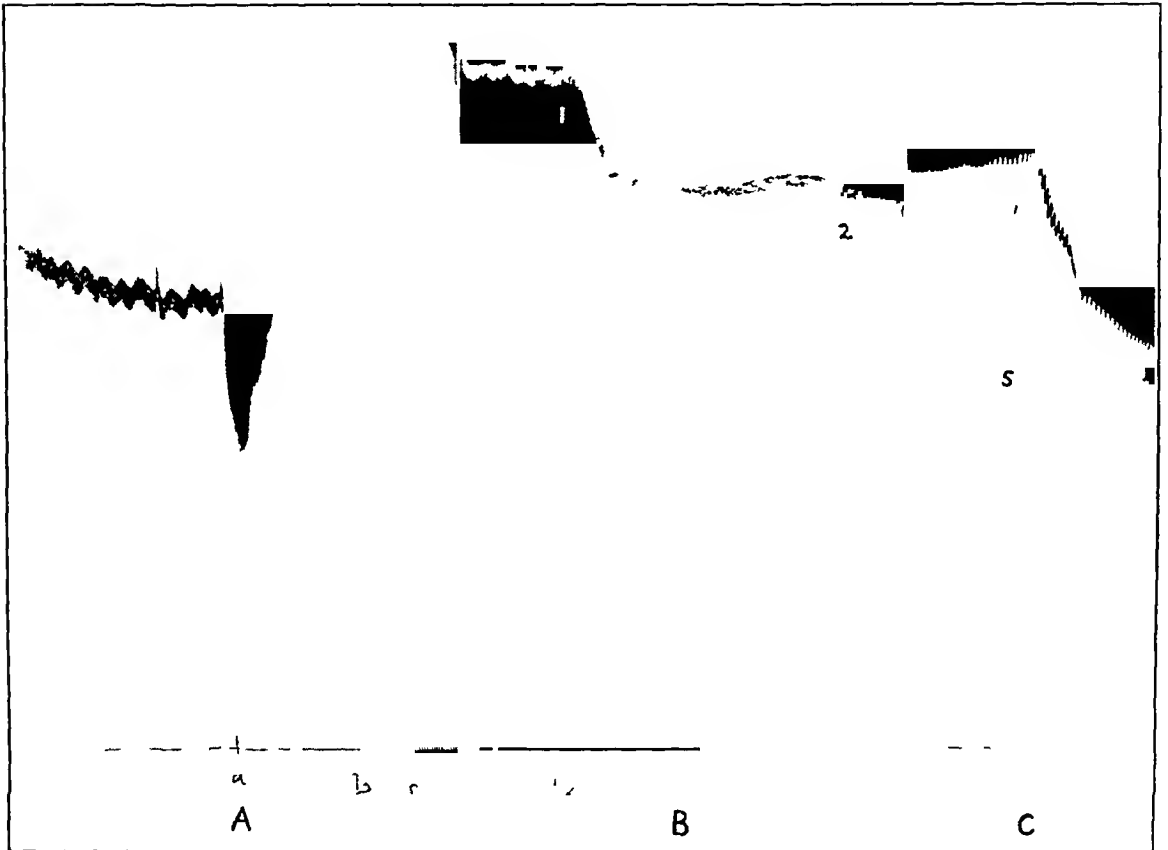


Fig 1—Examples of the effect of ether on the blood pressure of cats *A*, record from Experiment 85 *a*, ether on, *b*, reflex gone (ninety-five seconds), *c*, ether off (140 seconds), *B*, record from Experiment 69 1, ether on, 2, ether off (four minutes), *C*, record from Experiment 50 1, ether on, 2, reflex gone and ether turned off

obtained in from two to four minutes. If the administration of ether was continued longer, usually after about five minutes a second fall in blood pressure occurred which quickly caused the death of the animal.

The second class of cases shown in the accompanying table includes those animals in which the primary fall in blood pressure was not followed by a rise but continued at the new lower level. It will be noted that in these cases the fall in pressure was not very marked, so

that, although there was no recovery, the blood pressure was still at a high level when the eye reflex disappeared. An example of this type of reaction is shown in Figure 1 *b*.

In only three out of the series of twenty cats was there a failure to maintain a normal blood pressure, as is shown in the table. In these three cases, there was a continued fall in pressure, so that the ether had to be discontinued before deep anesthesia was attained. This is the type of blood pressure change found, to a more marked degree, in shocked animals. It is illustrated in the record shown in Figure 1 *c*. In these cases, the animals had previously undergone severe operation, in one case, decerebration, in the other two, chest operations, and it is probable that this condition of ether sensitiveness did not exist previous to these procedures.

In some cases, as the depth of anesthesia increases, the respiration may become gradually more shallow, even before the eye reflex disappears. It seemed possible that part of the recovery of the blood pressure which occurs during the administration of ether might be accounted for by an asphyxia produced in this way. That this factor may influence the extent of recovery is indicated in a few experiments in which there was a slightly less marked recovery with artificial respiration. Frequently, however, the rise obtained under regular artificial respiration is equal to that under natural respiration.

By giving the ether gradually, it is always possible, in the normal animal, to attain a depth of anesthesia where the eye reflex is abolished, without the intervening drop in blood pressure. If ether is inhaled while the animal is anesthetized, the effect on the blood pressure is very much less than when it is given to an animal that is not already under the influence of ether. Similarly, the fall in pressure caused by the intravenous injection of ether is much less in the deeply anesthetized animal. In eight out of nine cats tested with ether injections, this was true. These animals repeatedly gave greater drops in pressure when the anesthetization was light. For example, in Experiment 53, in six trials there was an average fall of 19.3 mm following the injection of 1 c.c. of a saturated solution of ether in physiologic solution of sodium chloride at room temperature (about 8 per cent ether) during light anesthesia, whereas, with deep etherization, a similar series of six injections caused an average fall of only 8.3 mm, the original pressure being the same in each case.

The significance of these pressure changes will be considered later in relation to the action of ether on the separate parts of the circulatory system.

*The Effect of Ether on the Blood Pressure of the Shocked Animal*  
—In these experiments, methods were used in obtaining the records and in administering the ether similar to those described for the normal

animal In fact, in most cases, records of blood pressure showing the effects of ether before and after shock were obtained from the same animal, all the external conditions remaining constant The effects on the blood pressure are strikingly different after shock has developed A typical result is illustrated in Figure 2 Just as in the normal animal, the first effect is a sharp drop in pressure, but this is not followed by a recovery, instead, there is a further fall which rapidly approaches zero, often before the eye reflex disappears Even when ether is administered more gradually and to a much less degree, the pressure falls, though

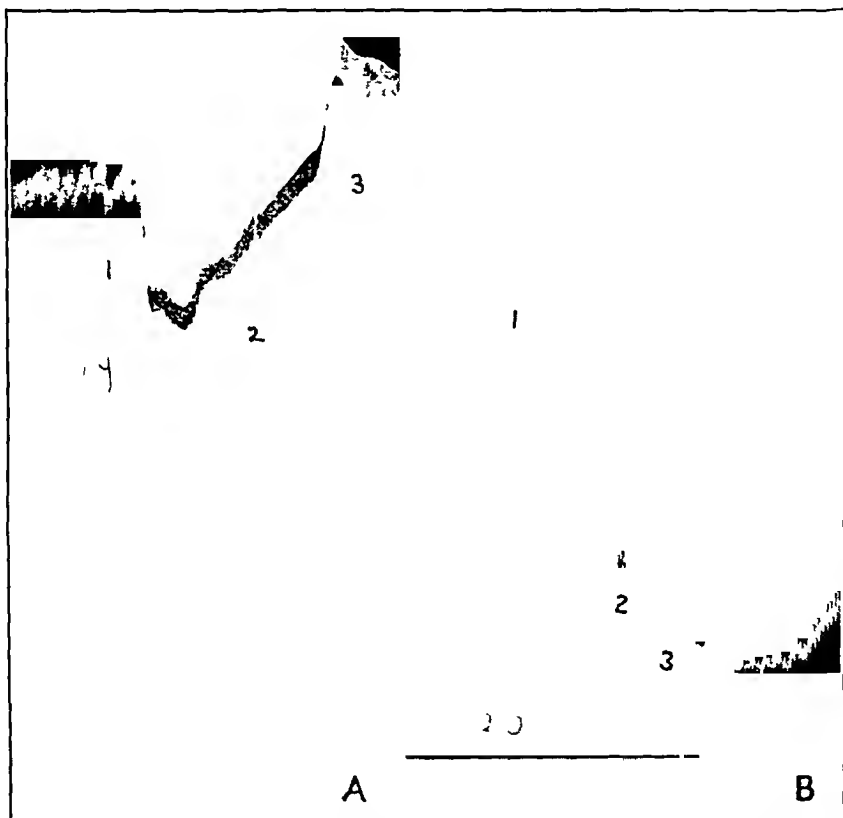


Fig 2—The influence of strong ether on the blood pressure before and after shock 1, ether on, 2, eye reflex gone, 3, ether off A, ether effect before shock, B, a record taken three hours later after shock had developed, but under otherwise similar conditions

not so abruptly In a series of over fifty animals this increased sensitiveness to ether was so constant that it is unnecessary to tabulate the individual experiments Regardless of how the ether is administered, the blood pressure in the shocked animal will show a considerable decrease at the point where the eye reflex is just obliterated, whereas, in the normal animal, the pressure is but slightly, if at all, below that before anesthetization The significance of this change in the effect of ether will be discussed later



*The Effect of Nitrous Oxid-Oxygen Anesthesia on the Blood Pressure*—In the course of our work at the Dijon laboratory, some incidental observations were made by Dr Cannon and myself on the effects of nitrous oxid-oxygen anesthesia on the blood pressure of shocked animals, which may be briefly mentioned here. It was found possible to induce in the shocked animal a full degree of anesthesia without any fall in blood pressure. In the same animal, the inhalation of ether to the same depth of anesthesia, i. e., until the eye reflex disappeared, would cause the usual drop in blood pressure. The absence of circulatory depression with nitrous oxid and oxygen is true only when they are administered in the most favorable proportions, the best results being obtained by the use of the largest proportion of oxygen com-



Fig 3—Comparison of the effect of ether and of nitrous oxid and oxygen in a shocked animal. In each case, the anesthetic was given until the eye reflex just disappeared, when the record was taken. 1, Blood pressure drop produced by ether; 2, blood pressure drop produced by nitrous oxid and oxygen, 6 1; 3, blood pressure drop produced by nitrous oxid and oxygen, 5 1; 4, blood pressure drop produced by nitrous oxid and oxygen, 4 1; 5, blood pressure drop produced by nitrous oxid and oxygen, 3 1; 6, blood pressure drop produced by ether.

patible with the production of the desired depth of anesthesia. This result can usually be obtained with a mixture of from three or four parts of nitrous oxid to one part of oxygen. Higher concentrations of nitrous oxid may result in a fall in blood pressure nearly as great as that from ether. In some animals, it is not possible to get complete abolition of the eye reflex without some fall in pressure, but this fall is always less than that resulting from ether (Fig 3).

#### THE EFFECTS OF ETHER ON THE HEART

*Literature*—The importance of the influence of anesthetics on the heart was early recognized, and a considerable amount of careful experimental work has been done on the action of chloroform and ether

much of which was carried out from the point of view of determining the relative toxicity of these two drugs Knoll,<sup>14</sup> in 1879, made a comparative study of the effects of chloroform and ether on the circulation in rabbits, from which he concluded that ether in moderate doses was limited in its influence to the vasomotor system, while chloroform had a direct injurious action on the heart Diaballa<sup>26</sup> was the first to make a quantitative study of the relative toxicity of different anesthetics on the heart He transfused the isolated frog heart with solutions of sodium chlorid, to which were added varying amounts of the drugs studied A chloroform concentration of 0.126 per cent was sufficient to bring the heart to a standstill within two and a half minutes, while with ether it was necessary to use a concentration of 2.84 per cent to produce the same effect Ether in a concentration up to 0.235 per cent was without influence on the heart In perfusion experiments carried out by Osthelder<sup>27</sup> on the frog heart, it was found that the employment of either chloroform or ether resulted in a depression of its function, the effects being much more marked with chloroform If the amount of ether was sufficiently small, stimulation of the heart resulted McWilliam<sup>18</sup> reports a series of experiments on cats in which he obtained simultaneous records of the blood pressure and of the auricular and ventricular contractions, and recorded the variations produced by the inhalation of ether and chloroform under artificial respiration It was found that with either of these substances, when given in an amount sufficient to cause a disappearance of the corneal reflex, there was a drop in the blood pressure along with a decrease in the functional activity of the heart The conclusion was reached that chloroform depresses the heart directly, while the effect from ether is secondary to a lowered blood pressure The grounds for the conclusions regarding the effects of ether are not evident from the results presented, the fall in pressure might with equal probability be interpreted as being secondary to the weakened heart action In the isolated heart-lung preparation of rabbits, Bock<sup>21</sup> observed little or no drop in pressure from ether administered in the inspired air, whereas the administration of chloroform resulted in a marked drop The concentrations of the anesthetics used are not given Muehlberg and Kramer<sup>28</sup> studied the effects of ether and chloroform injected directly into the circulation Both substances caused a rise in blood pressure when introduced into the carotid, but, when injected intravenously, a fall in pressure It was concluded that ether injected intravenously is more toxic than

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26 Diaballa Arch f exper Path u Pharmakol 34 147, 1894

27 Osthelder Diss Wurzburg, 1896

28 Muehlberg, William, and Kramer, S P The Action of Toxic Doses of Ether and the Influence of Amyl Nitrite Thereon, J A M A 48 2093 (June 22) 1907

chloroform and that the fall in pressure is due to a direct depressant action on the heart. Tunnichiff and Rosenheim<sup>29</sup> transfused the isolated mammalian heart with Locke's solution. The addition of 0.01 per cent of chloroform had a noticeable influence, while 0.10 per cent brought the heart to a standstill. Ether was much less effective, causing only a temporary irregularity and slowing of the heart. However, concentrations of ether were used only up to 0.20 per cent, which were based on the determinations of Franz,<sup>30</sup> who found in the blood of etherized animals only 0.05 per cent of ether. More recent determinations have indicated that this figure is too low. Nicloux<sup>31</sup> gives from 0.13 to 0.15 per cent of ether as average figures for the amount present in the blood during deep anesthesia. Storm van Leeuwen<sup>32</sup> found that at the point where the eye reflex disappeared the percentage of ether in the blood by weight was 0.18. Additional experiments by Schram, Storm van Leeuwen and van der Made<sup>33</sup> showed that a concentration of from 0.101 to 0.212 per cent was necessary before any harmful effects on the circulation were evident, and that the complete arrest of the heart occurred with a blood ether content of 0.250 per cent. With the removal of vagus influences, and by maintaining artificially an adequate circulation, the minimum lethal dose rose to 0.553 per cent. Since drops in blood pressure were obtained with concentrations of ether insufficient to affect the isolated heart, the conclusion was reached that the fall in pressure is due to an influence on the vasomotor and vagus centers. Loeb<sup>34</sup> also investigated the action of ether on the isolated cat heart, perfusing with a blood-sodium chlorid mixture. He found 0.133 per cent to be the minimum harmful dose, and 1.7 per cent the minimum lethal dose. Perfusion experiments on the isolated turtle heart were carried out by Vernon<sup>35</sup>. Ringer's solution, containing various concentrations of ether and chloroform, was perfused through the aorta, and the effect on the extent of contraction recorded. In concentrations of ether above 0.10 per cent, the heart was affected, a 0.20 per cent solution reducing the extent of the contractions to 75 per cent of their original value. Chloroform was about twenty-five times as effective.

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29 Tunnichiff and Rosenheim. *Proceedings of the Physiological Society, J. Physiol.* **29** 15, 1903.

30 Franz. *Dissert.* Wurtzburg, 1895.

31 Nicloux. *Les Anesthésiques généraux au point de vue Chimico-physiologique*, Paris, 1908.

32 Storm van Leeuwen. *Arch. f. d. ges. Physiol.* **165** 594, 1916.

33 Schram, Storm van Leeuwen and van der Made, *Arch. f. d. ges. Physiol. (Pflüger's)* **165** 123, 1916.

34 Loeb. *Arch. f. exper. Path. u. Pharmacol.* **52** 459, 1905.

35 Vernon. *J. Physiol.* **45** 194, 1910.

The experimental evidence briefly summarized above strongly favors the assumption that ether, in the concentrations present in ordinary anesthesia, causes a decrease in the efficiency of the heart, which might account for any fall in arterial pressure occurring under ether anesthesia. In the course of this investigation, a few experiments were made on the action of ether on the heart. Though confirmatory of the results obtained by previous workers, they may be worth recording here. Information was gained in three ways: from experiments on the heart volume, from the contractions and output of the cold-blooded heart, and from blood pressure changes.

*The Effect of Ether on the Tonus of the Heart*—In order to determine what part the heart played in the blood pressure changes induced by ether, it was of interest to know what changes occurred in the heart under the experimental conditions described in the first section. To do this, heart volume records were made, using the pericardial sac as an oncometer. This method has been employed by a number of the older investigators for the examination of the systolic output under various conditions, and is described in a paper by Johansson and Tigerstedt<sup>36</sup>. Schäfer<sup>37</sup> states that the method has been found unsuitable on account of the elasticity of the pericardium and interference with the action of the heart by the surrounding fluid. These objections doubtless hold for the examination of the systolic output, but do not apply to the use of the method for investigating the changes in the heart volume occurring over a period of time independently of the individual contractions. The advantage of the method over others is its extreme simplicity. A glass cannula is inserted into a small opening in the pericardium and tied in place. It is connected directly to a volume recorder, the volume changes of the heart being transmitted through some fluid (a 6 per cent gum-salt solution was found satisfactory). The chest can be closed and the animal allowed to breathe naturally after the operation is completed. Ether was administered through a tracheal cannula in the usual manner.

In this way, heart volume records showing the effects of ether were obtained in eleven cats, all of which gave consistent results as often as the inhalation of ether was repeated. From the beginning of the administration of ether, there is a relaxation of heart tone, as indicated by an increase in volume. This becomes progressively greater as the anesthesia becomes deeper, the maximum dilatation being reached only with the death of the animal. This is true regardless of the pressure changes which may occur as a result of the ether, the heart volume increasing through the primary fall and the subsequent recovery. In

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36 Johansson and Tigerstedt. *Skand Arch f Physiol* 1 331, 1889.

37 Schäfer. *Text Book of Physiology*, 1900, Vol 2.

one unusually resistant animal, it was possible to give ether in relatively strong concentration with practically no effect on the blood pressure until after the eye reflex had disappeared. The heart volume record registered the usual increase, giving further evidence that the changes recorded represent a true change of heart tone independent of any blood pressure changes. A record taken from this animal is given in Figure 4. A second tracing is illustrated in Figure 5, taken from the same experiment, with the animal under artificial respiration and the chest open, showing that the change is not dependent on any effect on the respiration or tone of the chest muscles. Similar results are obtained after cutting

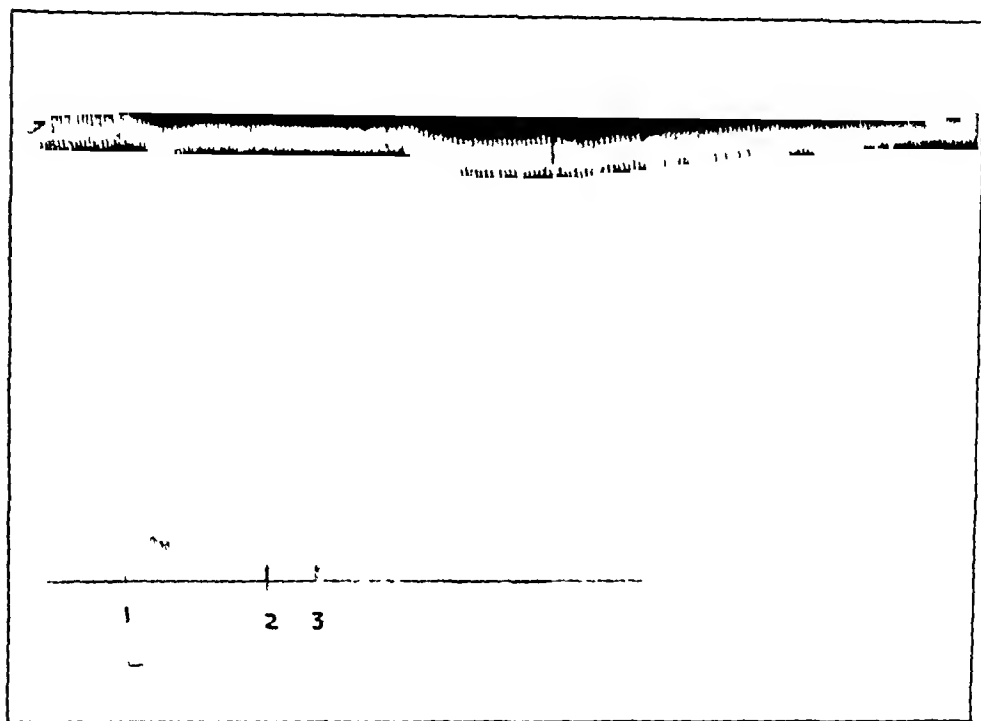


Fig 4—Effect of ether on the heart volume. top record, blood pressure with mercury manometer, middle record, heart volume taken with a volume recorder, a rise indicating an increase in volume, bottom record, zero blood pressure and signals. 1, ether on, 2, eye reflex gone, 3, ether off after two and one-half minutes.

both vagi, although the blood pressure changes and increase of heart volume may be less marked under these conditions.

A similar but very transitory effect on the heart volume is produced by the intravenous injection of small amounts of ether dissolved in Ringer's solution. This is illustrated in Figure 6.

Since the method does not exclude effects which might be produced by volume changes of the auricles and entering veins, it might be argued that the effects recorded are due to a passive filling of these parts. This is made quite improbable from the facts that (a) the effect is inde-

pendent of pressure changes, (b) it is not necessarily accompanied by a slowing of the heart, and (c) the administration of ether is accompanied by a peripheral constriction (to be demonstrated later) That the increases in heart volume registered are not due to the passive effects resulting from the fall in arterial pressure or to a dilatation of the blood vessels can be demonstrated by bringing about these changes artificially through the occlusion of certain areas of the circulation The removal from the carotid of a clip which has been present for some

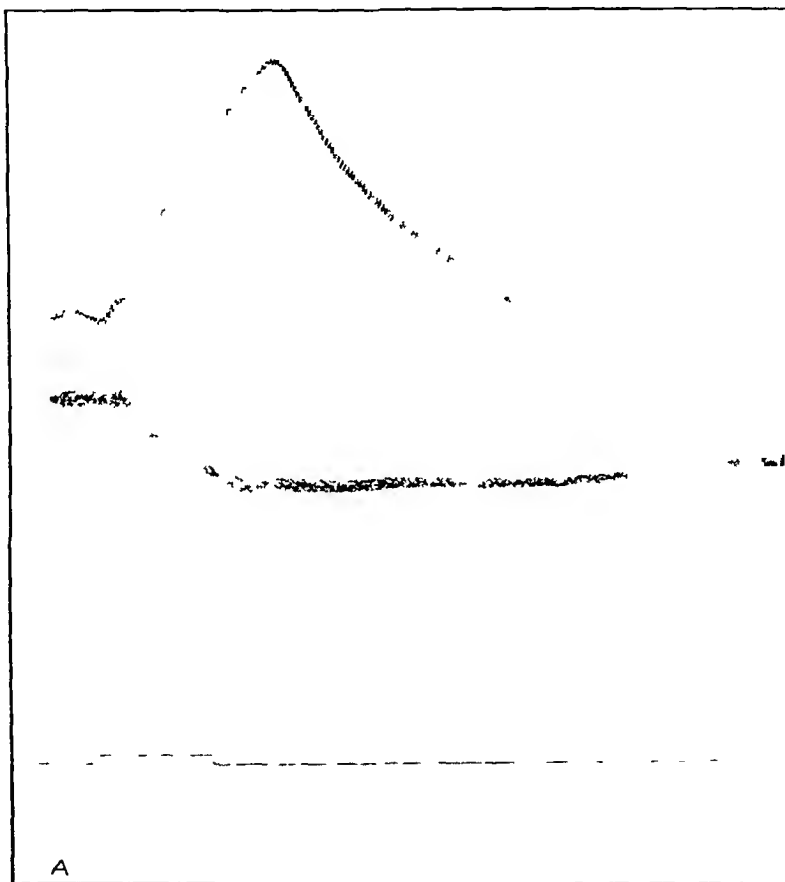


Fig 5—Tracing taken from the same animal as in Figure 4, but with the chest widely opened and under artificial respiration Top record, heart volume, the rise representing an increase in volume, middle record, blood pressure with mercury manometer, bottom record, zero blood pressure and signals showing time of ether administration

minutes results in a decrease of the peripheral resistance with a consequent fall in blood pressure, but the change in the heart volume record is just the opposite from that caused by ether, that is, there is a small decrease

The question may be raised as to whether the relaxation of heart tone is accompanied by a decrease in the output of blood That such a

relationship holds is indicated by the evidence. Certainly it is true in the isolated heart of the cold-blooded animal, where, in experiments presently to be described, ether causes a marked decrease in tone and at the same time reduces the extent of contraction and the output per minute. Moreover, the effects on the volume are similar to those produced by vagus stimulation, carbon dioxide and other agents which are known to decrease the heart output. The progressive character of the dilatation, as the anesthesia deepens, until the time of death, is also an indication that the change is one of continuously decreasing output.

*The Effect of Ether on the Isolated Cold-Blooded Heart*—In order more directly to observe the cardiac effects of ether in the concentrations present in the blood, some tests were made on strips of muscle taken

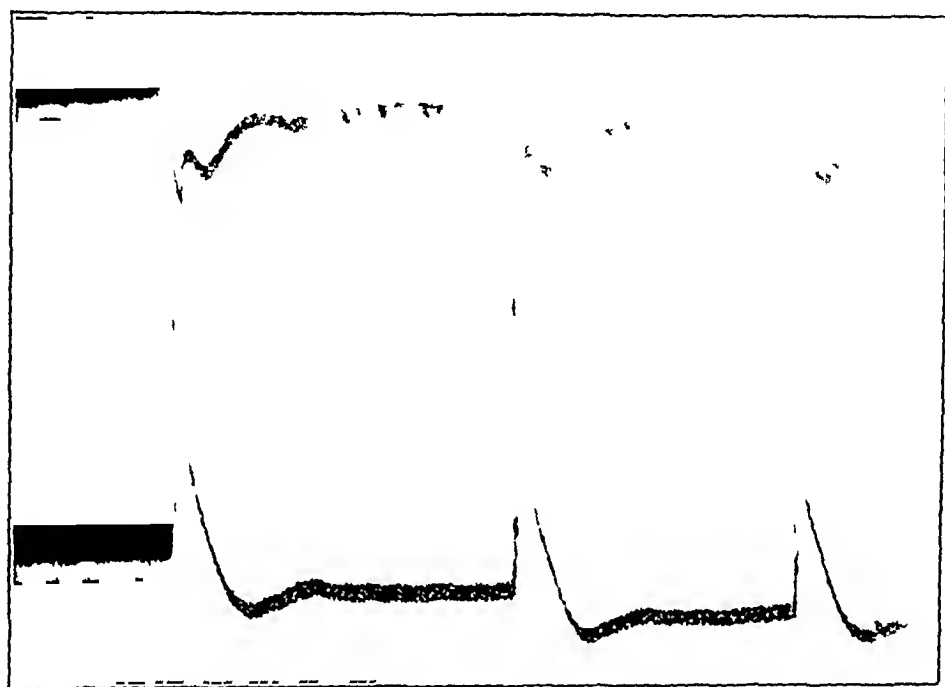


Fig 6—Effect of intravenous injections of ether on the heart volume. Record shows the effects of three successive injections of 1 cc of physiologic solution of sodium chlorid saturated with ether at room temperature. Upper record, blood pressure with mercury manometer, middle record, zero blood pressure, lower record, heart volume, a rise representing an increase in volume.

from the auricle of the turtle heart. Records were obtained of the rate and extent of contraction by simply attaching one end of the auricular muscle to a heart lever and the other to a glass rod which extended down into a beaker of Ringer's solution to which the various concentrations of ether could be added.

When first removed from the animal, the strips of auricular muscle always showed marked rhythmic changes in tone. On changing the Ringer's solution to one containing 0.18 per cent ether by weight, there

was a gradual but immediate fall in tone and the rhythmic variations ceased, as shown in Figure 7. When a change was made to a fresh solution without ether, there was a rapid recovery of tone and resumption of the periodic contractions. It will be noted that there is some decrease in the extent of the contractions. In some cases, an exposure to this concentration of ether for twenty minutes resulted in a decrease to about half of the original amplitude. In experiments on the isolated frog heart, later to be reported in detail, it was found that ether, used in this concentration, produces a marked reduction in output, along with a decrease in the extent of the contractions.

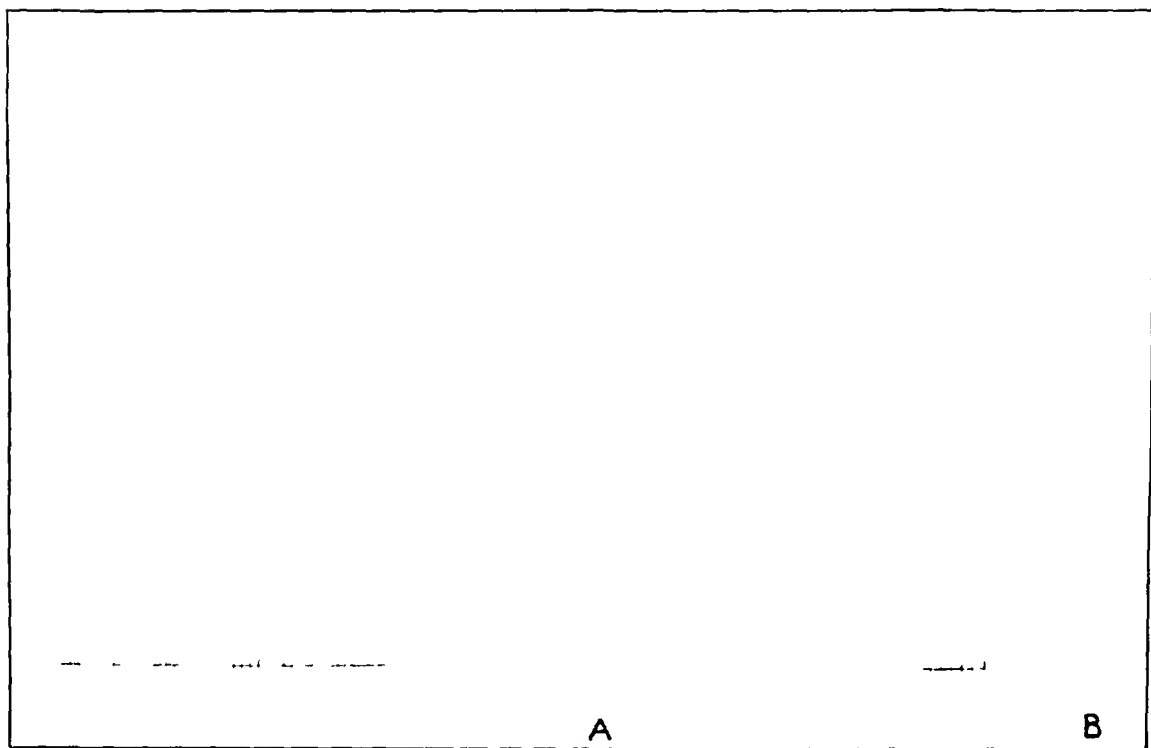


Fig 7—The effect of a weak ether solution on the isolated auricle of the turtle heart. *A*, record taken from auricle in Ringer's solution, *B*, record taken immediately after changing to a solution containing 0.18 per cent of ether by weight, upper record, auricular contractions, lower record, time in five second intervals.

These results are confirmatory of a number of observations previously recorded in the literature. They are of interest in connection with the work of Storm van Leeuwen,<sup>32</sup> referred to above, who found that in the cat the eye reflex disappeared when the concentration of ether in the blood reached 0.18 per cent by weight. This concentration of ether is sufficient in the cold-blooded heart to cause a decrease in tone and extent of contraction, and it is probable that in the cat the effect, at a higher



temperature, would be even greater and might thus account for the fall in blood pressure occurring in ether anesthesia

*The Effect of Ether on the Heart Deduced from Blood Pressure Changes*—An examination of the blood pressure effects from ether, in connection with the conditions of peripheral tone, reveals further information. Turning back to the blood pressure records of the normal cat (Fig 1), it will be remembered that there is a sharp initial drop in pressure, followed, in most cases, by recovery. Simultaneous plethysmograph and perfusion experiments on the hind leg, described in the section following, show that during this drop there is no dilatation of the blood vessels whatever—indeed there may be constriction. The

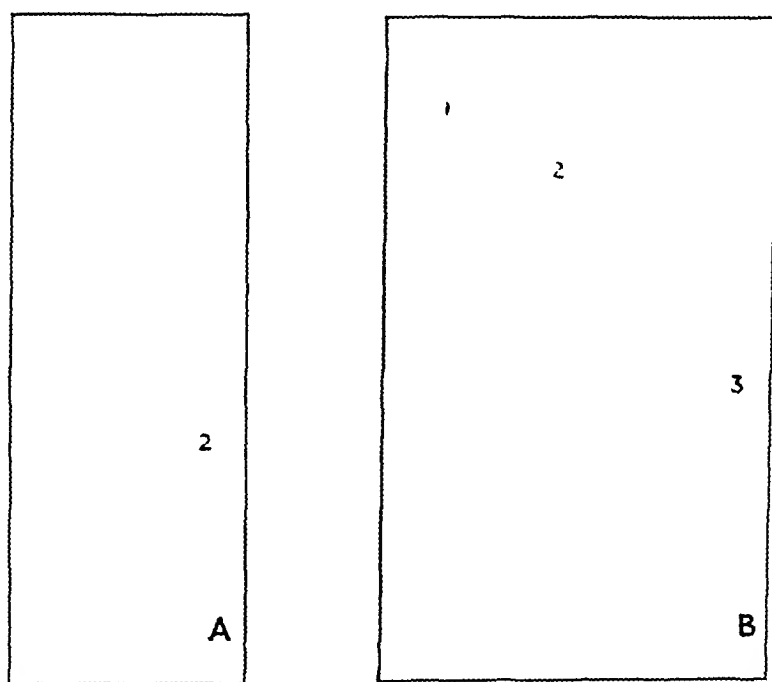


Fig 8—The effect of cutting both vagi on the fall in pressure produced by ether in a shocked animal, *A*, ether fall produced before cutting vagi, *B*, the same after cutting vagi, 2 marks the time when the eye reflex could no longer be elicited, and 3, after four minutes of ether inhalation

pressure fall must, therefore, be due to an influence on the heart. The later drop in pressure occurring during very deep etherization may be due in part to vasomotor effects, but this does not concern us here.

The vagus center undoubtedly modifies to some extent the changes in blood pressure resulting from the administration of ether. Knoll<sup>14</sup> observed that animals with cut vagi were able to withstand much larger doses of ether than the animals in which the vagi were intact. Schram, Storm van Leeuwen, and van der Made<sup>33</sup> found that it required an average concentration of 0.31 per cent of ether in the blood to bring the

heart to a standstill in animals under atropin, or with cut vagi, while, in the intact animal, the heart was brought to a standstill by a concentration of 0.25 per cent. An example of the effect of the same dose of ether before and after cutting the vagi in a shocked animal is given in Figure 8. A similar effect was observed on the respiration, animals with cut vagi continuing to breathe for a longer period under strong ether inhalation.

In the transitory effect produced by the injection of small amounts of ether into a vein, there is always a primary drop in blood pressure which may be followed by a rise above normal. In this case, the heart is reached before the vasomotor center or peripheral vessels. On the other hand, if the injection is made into the carotid artery toward the head, the relations are reversed: the vasomotor center is first reached, resulting in a rise in pressure, followed later by a fall. The time relations here indicated strongly support the idea that the fall in pressure is due to an influence on the heart. These experiments will be considered in greater detail in connection with the study of the vasomotor effects of ether.

*The Effect of Ether on the Heart in Shock*—No references have been found to experimental work on the effects of anesthetics on the heart in shock. There is much evidence, however, that the function of the heart is in no way depressed in this condition, and that it is still capable of doing the normal amount of work<sup>38</sup>. While direct experimental examination as to this question has not been made, no indication of an increased ether effect on the heart has been observed in the course of these experiments. The investigation of the problem is made difficult by the marked drop in blood pressure resulting from the administration of ether in shock. This interferes with plethysmograph records and also with the nutrition of the heart, thus causing a depression independently of the direct action of ether on the organ. The administration of ether unquestionably results in an earlier cessation of the heart beat in the shocked animal, but this may well be due to the secondary effect of the low blood pressure. There is, in fact, some evidence that the heart may become more resistant under the conditions of those experiments in which ether is repeatedly given over long periods. In a number of animals in which the blood pressure had been low for some hours and a considerable additional fall was not possible, the heart was found to be exceedingly resistant to outside influences. Ether, given in high concentration over long periods, had but little effect, while earlier it would rapidly cause the pressure to fall to zero, the death of the animal ensuing. Perfusion experiments now being carried out on the isolated frog heart indicate that a certain tolerance may be acquired. If the

perfusion is continued long enough, the heart will recover from a toxic concentration of ether, which at first produces a marked depression. Similar observations were made by Kuno<sup>39</sup> and by Ransom,<sup>40</sup> in the perfusion of the frog heart with alcohol. The blood pressure experiments mentioned earlier show that the effect of a given amount of ether is very much less when the animal is already under the influence of ether. This, however, may be due to an adaptation of the animal as a whole, rather than to a specific influence on the heart. There is no reason to suppose that the increased tolerance to ether bears any relationship to the changes occurring in shock; on the contrary, it is due rather to changes brought about by the prolonged administration of ether.

*Modification of the Effects of Ether on the Circulation by Epinephrin*  
—Interesting light is thrown on the problem in the change produced by epinephrin on the reactions of the shocked or "sensitive" animal. Early in the research, it was noted that certain animals which had been resuscitated by an injection of this substance into the carotid artery after an overdose of ether lost a large part of the sensitiveness to ether which they had previously exhibited. Further experiments have established the fact that this was due to an influence on some part of the circulation, probably the heart. In all, fourteen cats were examined for the effect of epinephrin on the circulatory depression produced by ether. In some of these cases, it was given as a restorative measure after an excessive dose of ether; in others, injections were made for the purpose of comparing the reaction to ether before and after the injection. The injections were made directly into the circulation in fairly large doses (from 0.1 to 1 mg.). The immediate effect was, of course, a prolonged increase in blood pressure, followed by a fall, usually to less than the original level. In a number of instances, ether could be administered at this point in high concentration without any effect whatever on the blood pressure, whereas, a few moments earlier, before the injection of epinephrin, a considerably smaller dose of ether would cause the pressure to fall to zero. In other cases, the protection was not so complete, but in all but one of the animals there was a considerable reduction in the ether effect. This one exception showed no appreciable change in the ether fall. The original sensitiveness to ether only gradually returns, in most cases the influence of the epinephrin still being apparent an hour after its injection. This is true both for inhaled ether and for ether given by intravenous injection. In Experiment 39, the intravenous injection of 1 c.c. of a saturated solution of ether in Ringer's solution caused a drop of 26 mm. in the arterial pressure, but, after the injec-

39 Kuno Arch. internat. de pharmacol. **77** 206, 1914

40 Ransom, F. J. Physiol. **53** 141 (Sept.) 1919

tion of 0.3 mg of epinephrin, this amount of ether caused no fall whatsoever. One hour later, there was some return to the sensitive condition, the injection of 1 c.c. of the ether solution resulting in a 9 mm drop in pressure. The influence of epinephrin on the blood pressure drop, caused by inhaled ether in a sensitive dog, is illustrated in Figure 9. The first record shows the effect of a rather light dose of ether inhaled until the eye reflex just disappeared. This animal had gradually become sensitive to the effects of ether through the course of the experiment, this amount of ether having no influence on the blood pressure earlier in the day. Shortly after this record was obtained, the animal was

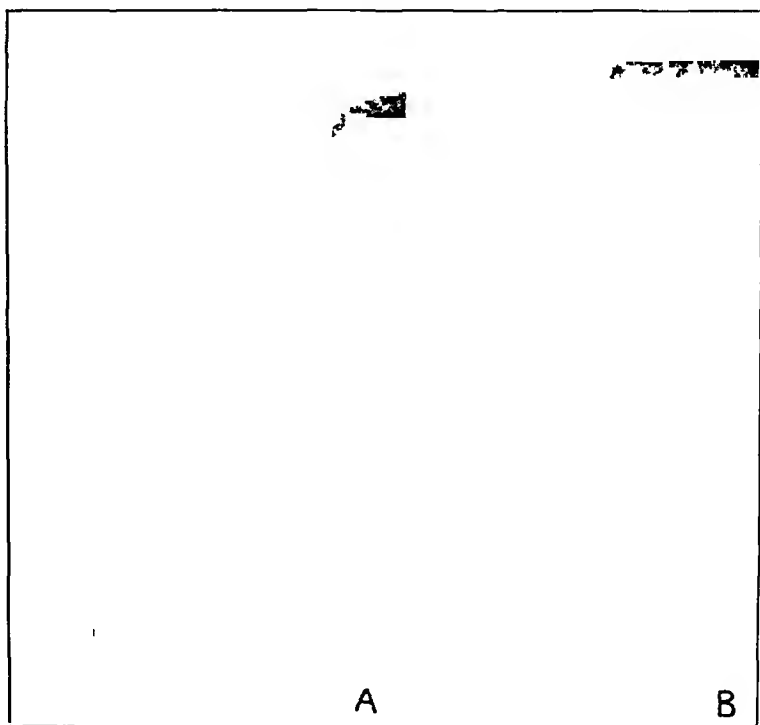


Fig 9—The influence of epinephrin on the fall in blood pressure produced by ether. *A*, before the administration of epinephrin, *B*, after the animal had been resuscitated with a large dose of epinephrin. In each case, the inhalation of ether was continued to the point where the eye reflex disappeared.

overetherized and had to be resuscitated with a large dose of epinephrin injected directly into the carotid artery. Following its recovery, the animal was very resistant to the effects of ether. The second record in the illustration was taken nearly two hours later. It shows the absence of blood pressure influence by the inhalation of ether under the same conditions as in the first record, i.e., in both cases, the animal was anesthetized until the eye reflex could no longer be elicited.

Evidence has already been presented indicating that the fall in blood pressure produced by ether is largely due to an influence on the heart

The fact that epinephrin reduces this effect at once suggests that it also acts through the heart in an antagonistic manner. There are a number of observations which support this view. In the course of these experiments, animals were not infrequently overetherized to the extent that there was a complete cessation of the heart beat. While they are in this condition, a strong injection of epinephrin directly into the arteries is always effective in restoring the beat, even though at that time the heart is undoubtedly surrounded by fluid containing ether at a toxic concentration. Gottlieb<sup>41</sup> found that epinephrin exerted a beneficial effect in chloroform poisoning. In a series of experiments on the perfused isolated heart of rabbits and cats, Gunn<sup>42</sup> showed that epinephrin can antagonize a concentration of chloroform which alone markedly enfeebles the heart's contractions. In some recent experiments, Ransom<sup>43</sup> has shown that, in the isolated frog heart, depressed by chloroform, there may be complete restoration by the addition of small quantities of epinephrin to the chloroform solution.

Since there is no good evidence that the fall in blood pressure resulting from the administration of ether is caused by any effects on the peripheral vessels, it is unlikely that the protecting effect of epinephrin can be explained through its effect on the blood vessels. Pituitary extract, which is practically without influence on the heart, but which causes strong contraction of the smooth muscle of the arterioles, is absolutely without effect in influencing the blood pressure fall from ether. If this drop were due to an effect on the peripheral resistance, it should be less marked after the administration of pituitary extract.

#### THE EFFECT OF ETHER ON THE BLOOD VESSELS

*Literature*—There is no agreement in the conclusions reached by different observers as to the influence of anesthetics on the vasomotor center, some reporting a dilatation of the blood vessels, and others a constriction under ether and chloroform. The direct consideration of the question is difficult, and many of the conclusions have been reached by inference from blood-pressure changes, etc., which probably accounts for some of the discrepancies. Moreover, the reactions resulting from the administration of anesthetics are not uniform and may be dependent on a number of factors. Since the blood pressure effects of chloroform are so marked, much of the earlier work has centered around the action of this anesthetic. Brief mention of these papers will be included in the following short review of the literature on the action of ether on the blood vessels.

41 Gottlieb Arch f exper Path u Pharmacol 38 99, 1897

42 Gunn Quart J Exper Physiol 7 75, 1913

43 Ransom, F J Pharm and Exper Therap 14 367 (Jan) 1920

Among observers reporting a dilatation of the peripheral vessels from the influence of chloroform are Scheinsson,<sup>44</sup> from a study of the blood vessels in the rabbit ear, the dilatation being attributed to a direct action on the vessel walls, Knoll,<sup>44</sup> from direct observations on the rabbit ear, and Bowditch and Minot,<sup>45</sup> from blood pressure changes in the dog. In a series of papers, Embley<sup>46</sup> adduces evidence to show that, while the direct effect of chloroform on the vasomotor center is stimulative, the net effect on the kidney and intestines is dilatation, owing to a local action on the arterial wall. Later, Embley and Martin<sup>47</sup> published further experiments, confirming the results of their earlier work, in which they perfused the isolated organs through an artificial heart-lung preparation. Pick<sup>47</sup> studied the vascular action of various poisons by perfusion and plethysmographic methods, and found that the employment of both ether and chloroform resulted in a dilatation of the vessels of the brain and abdominal organs. Weber<sup>48</sup> by means of a plethysmograph, measured the arm volume of patients, following operation under chloroform and ether anesthesia, and found evidence of vasodilatation, lasting for several days. McWilliam<sup>48</sup> concludes from his experiments, in which the blood pressure and heart contractions were simultaneously registered, that, in the cat, ether inhalation causes a fall in blood pressure through its action on the blood vessels. Muns<sup>49</sup> made plethysmographic records on the hind leg of dogs under deep ether anesthesia, these showed volume changes which were attributed to a vasodilatation. Schram, Storm van Leeuwen, and van der Made<sup>50</sup> report experiments in which they obtained a drop in blood pressure by ether in a concentration which other experiments had shown to be without effect on the heart, they therefore conclude that the effect was due to an influence on the vasomotor center.

Opposed to the foregoing are the conclusions reached by a considerable number of workers. Among those finding evidence of a peripheral constriction from chloroform are Arloing,<sup>50</sup> from observations of the blood flow in the carotid, Diastra,<sup>51</sup> Roy and Sherrington,<sup>52</sup> and Hurthle,<sup>53</sup> from measurements of the changes in the brain volume, and

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44 Scheinsson. *Abst Centralbl f d med Wissensch* **7** 506, 1869

45 Bowditch and Minot. *Boston M & S J* **90** 493, 1874

46 Embley. *Brit M J* **1** 817, 885, 951, 1902

47 Embley and Martin. *J Physiol* **27** 147, 1905

48 Weber. *Med Klin* **11** 991, 1915

49 Muns, W. C. *Ann Surg* **64** 645 (Dec.) 1916

50 Arloing. *These*, Paris, 1879

51 Diastra. *Les Anaesthetiques*, 1890

52 Roy and Sherrington. *J Physiol* **11** 97, 1890

53 Hurthle. *Arch f d ges Physiol* **44** 596, 1889

Newman,<sup>54</sup> from direct observation of the pulmonary capillaries of the frog Gaskell and Shore<sup>55</sup> carried out elaborate experiments to determine the place of action of chloroform in depressing the blood pressure. Two animals were arranged so that the brain of one was supplied by the blood of the other and was therefore isolated from its own heart. By these experiments, it was shown that, when blood from a chloroformed animal was allowed to circulate through the head of the second animal, it caused a marked rise in blood pressure, thus demonstrating a direct stimulation of the vasoconstrictor center by chloroform. At the same time, there was a fall of pressure in the first animal due to depression of the heart. These results were confirmed by the injection of chloroform directly into the carotid artery, which also resulted in a rise in blood pressure. Sherrington and Sowton<sup>56</sup> found that the amount of fluid passing through the coronary circulation of the isolated mammalian heart considerably diminishes when saline containing chloroform is substituted for the saline solution, from which they conclude that chloroform causes constriction of the arterioles. Schafer and Scharlieb,<sup>57</sup> by determining the perfusion rate, using Locke's solution plus chloroform in various concentrations, found that, except in very dilute solutions, the arterioles were contracted by chloroform.

The effect of ether on the arterioles was investigated by Kemp,<sup>58</sup> from changes produced in the blood pressure and in the kidney volume. Ether gave an increase in the carotid pressure, along with a decrease in the volume of the kidney. Chloroform caused a fall in pressure and an increase in kidney volume. Duplay and Hallion<sup>23</sup> carried out a series of experiments on dogs to determine the causes of the variations in pressure produced by the inhalation of ether and chloroform. Along with observations on the heart and blood pressure, they made measurements of the kidney volume and reached the conclusion that the fall in pressure was due to an effect on the heart, and the rise to a stimulation of the vasomotor center. These anesthetics had a similar action, but with ether the heart depression was less and the stimulation of the vasomotor center much more intense. Likewise, the statement is made by Cushny<sup>24</sup> that the first effect is on the heart, which may result in an abrupt fall in pressure, but in other instances may be compensated for by vasoconstriction from reflex stimulation of the center, so that the blood pressure may rise while the heart is slowed. The experiments

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54 Newman J Anat & Physiol **14** 495, 1879

55 Gaskell and Shore Brit M J 1893, pp 105, 164, 222

56 Sherrington and Sowton Report of the Chloroform Committee, London, 1903

57 Schafer and Scharlieb Proceedings of the Physiological Society, J Physiol **29** 17, 1903, Tr Roy Soc, Edinburgh **51-52** 311, 1904

58 Kemp New York M J **70** 732, 765, 804, 1899

of Muehlberg and Kramer<sup>58</sup> show that when ether or chloroform is injected into the carotid artery toward the brain, the blood pressure rises, presumably from a direct stimulation of the vasoconstrictor center. Airila<sup>59</sup> has attempted to determine the place of action on the circulation of ether and chloroform, through simultaneous measurements of the blood pressure and of the blood flow from the heart and in the peripheral vessels, by means of a stromuhr. It was found that the administration of either ether or chloroform resulted in vasoconstriction, except in very high concentration, in which case there was loss of vascular tone. At the same time, there was a depression of the heart, especially under chloroform anesthesia. Pilcher and Sollmann<sup>60</sup> have made a series of studies on the action of various drugs on the vasomotor center as inferred from the rate of perfusion of fluid through the vessels of the spleen and kidney. Ether was administered either through a tracheal cannula or by the injection of a saturated solution of ether in physiologic solution of sodium chlorid. The conclusion was reached that, given to the point of deep anesthesia, ether may stimulate the vasomotor center or be without action. When stimulation occurred, it was attributed to an indirect action secondary to a respiratory or circulatory depression. In a study of the capillaries of the cat ear, Hooker<sup>61</sup> has observed that, following death from ether, there is a marked constriction of the vessels, followed later by dilatation. This constriction, however, is attributed to the effect of asphyxia.

In the clinical literature, the statement is frequently made that ether causes a dilatation of the blood vessels. This general belief appears to be based on the observation that in the early stages of anesthesia there is an extensive flushing of the skin surfaces. The cause of the dilatation of the skin vessels is not evident, but it may be associated with a constriction of the arterioles of the internal organs and consequent increase in pressure. There is some evidence indicating that constriction occurs less readily in the superficial vessels. Dixon<sup>62</sup> has found, for alcohol, that there is a rapid dilatation of the skin vessels and at the same time a constriction of the vessels of the muscle tissue, and, to a less marked degree, of the splanchnic area. Moreover, as has been shown by Dastre and Morat,<sup>63</sup> in ordinary asphyxia, the blood vessels of the ear, face and extremities dilate, while those of the viscera contract, the increase in pressure resulting from a predominance of vasoconstriction in the visceral area over dilatation of the superficial vessels.

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59 Airila. *Skand Arch Physiol* 40 241, 1920

60 Pilcher and Sollmann. *J Pharm and Exper Therap* 6 401, 1915

61 Hooker. *Am J Physiol* 54 30 (Nov ) 1920

62 Dixon. *J Physiol* 35 346, 1907

63 Dastre and Morat. *Recherches sur le système nerveux vasomoteur*, Paris, G. Neasson, 1884



In an effort to throw further light on the causes of pressure variations occurring during the administration of ether, observations were made on the condition of arterial tone simultaneously with the taking of blood pressure records. This was done mainly by measurements of the leg volume by means of a plethysmograph, and by observations on the perfusion rate of fluids through the arteries of the legs. Further information is obtained by observation of the effects of the direct injection of ether solutions into the veins and arteries, and also by an examination of the blood pressure curves in conjunction with the effects on the heart.

*Experiments on Leg Volume*—In the investigation of the effect of ether on the tone of the arterioles, a number of observations were made on the leg volume, as indicated by the plethysmograph. The very simple form of apparatus described by Dale and Richards<sup>64</sup> was employed. This consisted of a glass cylinder about 5 cm in diameter, over one end of which was tied a rubber dam, a circular hole in this rubber permitted the insertion of the leg of the animal and made a tight joint, which was further sealed with petrolatum. The other end of the glass cylinder was connected through rubber tubing to a volume recorder. Changes in leg volume were transmitted by means of water, with which the whole system was filled. Simultaneous blood pressure and leg volume records were registered on the kymograph. With the exception of the addition of the plethysmograph and recorder, the general arrangement of apparatus was the same as that already described for obtaining blood pressure records, and the method of ether administration was exactly the same. The experiments were all performed on cats under ether anesthesia.

By this method, leg volume determinations were made on eight animals, of these determinations, two were unsuccessful on account of difficulties in technic, and the remaining five uniformly showed a decrease in leg volume as often as the ether was administered. The method is not well adapted for the determination of vascular changes produced by ether, on account of the accompanying fall in blood pressure and the resulting decrease in leg volume. Undoubtedly, this factor accounts for part of the volume change recorded, but an analysis of the tracings indicates that there is, in addition, an active vasoconstriction. Figure 10 shows records taken from Experiment 59 c. In the first tracing, the plethysmograph record shows a decrease in the leg volume along with the fall in arterial pressure, but this decrease is maintained during the recovery of the pressure while ether is still being administered, and, therefore, cannot be accounted for by a passive collapse of the blood vessels, but rather must be due to an active constric-

64 Dale and Richards J. Physiol. 52:110 (July) 1918

tion In another experiment, tracings from which are illustrated in Figure 11, an animal was used which gave practically no fall in blood pressure, but which, nevertheless, showed the usual decrease in leg volume It is quite unusual to find an animal which shows so little change in the blood pressure from the inhalation of ether, but since such animals show the usual heart depression and the vasoconstrictor effects from ether, it seems probable that these two factors are so balanced that the blood pressure remains constant The second tracing shows the disappearance of the effect on the leg volume after cutting the sciatic and crural nerves to the leg, indicating that the vasocon-

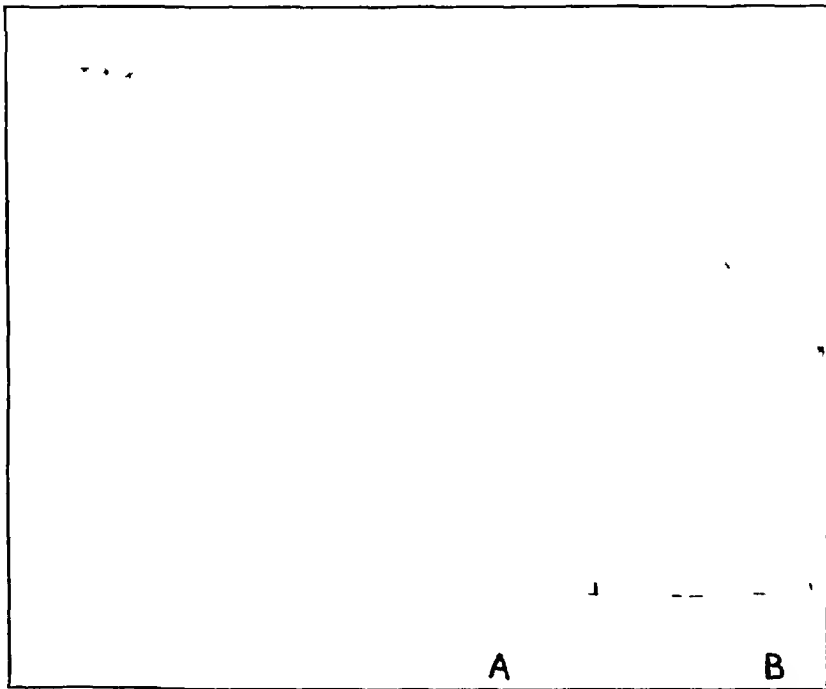


Fig 10—The effect of ether on the leg volume of an animal *A*, before shock, *B*, during shock Top record, blood pressure with mercury manometer, middle record, leg volume, a rise indicating a decrease in volume, lower record, zero blood pressure, with signal marks to indicate the duration of ether inhalation

striction results from a central influence rather than from a direct effect on the walls of the blood vessels After these records were obtained, the plethysmograph was shifted to the opposite leg and the procedure repeated with exactly the same result, ether no longer causing a reduction in the leg volume after the nerve supply was cut

From these experiments it may be concluded that the administration of ether, as in ordinary anesthesia results in a constriction of the peripheral vessels which is mediated through the vasomotor nerves How much of this effect is due to reflex stimulation of the center through

the lowered blood pressure, and how much to a direct stimulation of the center by ether, remains a question. Experiments to be described later indicate that both factors may enter into the result. That ether has no important direct vasoconstrictor action in the concentration present in the blood during surgical anesthesia in the normal animal is indicated by the leg volume experiments described above. If any part of this vasoconstriction was due to a direct action on the walls of the blood vessels, the effect should persist after nerve section. The fact that there is no dilatation in these experiments cannot be taken as proof that ether does not have a direct vasodilator effect, for these

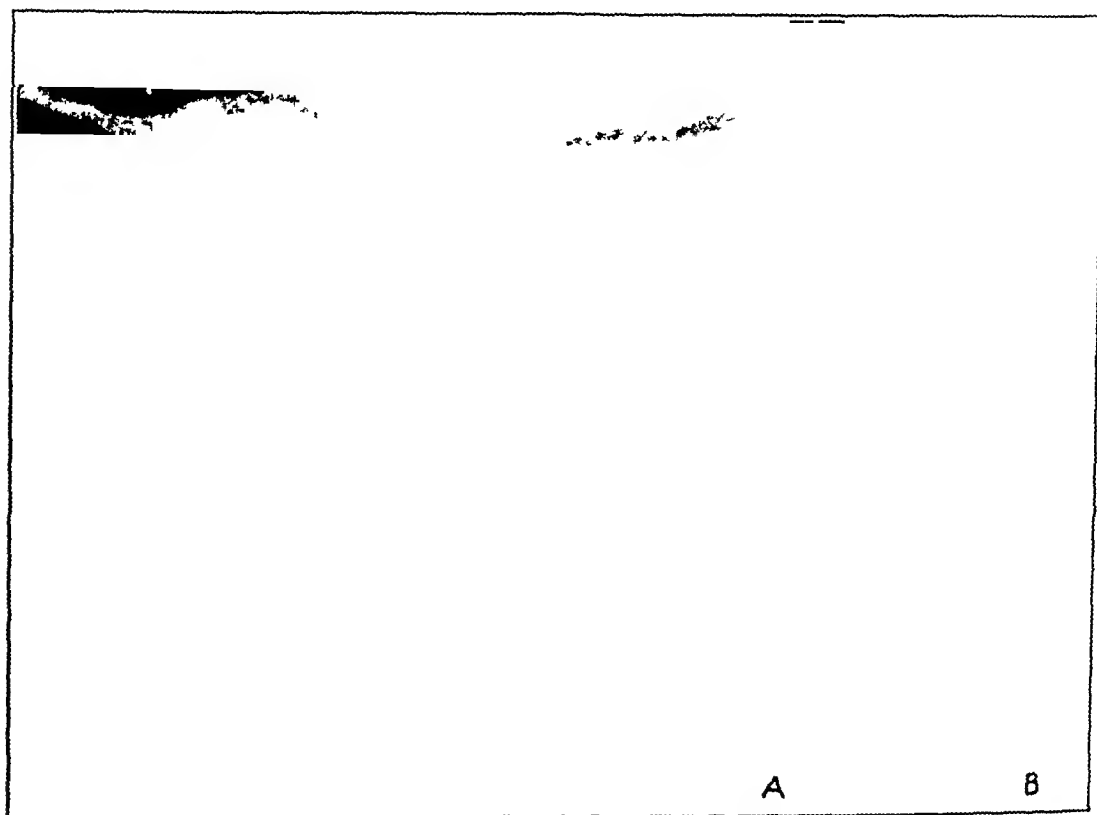


Fig 11—The effect of ether on the leg volume. *A*, in intact animal, *B*, after cutting all the nerves to the leg. Upper record, blood pressure with mercury manometer, middle record, leg volume, a rise in the curve indicating a decrease in leg volume, lower record, zero blood pressure, showing periods of ether inhalation.

observations were made within a short period after cutting the nerves. As has been pointed out by Dale and Richards,<sup>64</sup> it is important to take into consideration the almost maximum vasodilatation which occurs in the vessels of the leg immediately after its nerves are cut, any further dilatation being impossible.

The demonstration, by the plethysmograph and by perfusion experiments described below, that there is actually vasoconstriction in the

hind legs under ether anesthesia in the intact animal shows, however, that if there is any direct relaxing effect on the walls of the blood vessels, it is very slight and not sufficient to overcome the constrictor effect produced by the increased tone of the vasomotor center. Even under deep anesthesia, the vasomotor reflexes, as demonstrated by the asphyxial rise in blood pressure, are still functioning.

*Experiments on Perfusion Rate*—In an attempt to obtain further evidence on the condition of arterial tone in ether anesthesia, perfusion experiments were carried out. The method used was a modification of that described by Bartlett<sup>65</sup>. The perfusion fluid was injected through a buret, which was connected directly with the artery by means of a wash-out cannula. A side tube on the buret, connected with a bottle of Ringer's solution, served to refill the buret to the original level after each injection. The liquid in the buret was subjected to a constant pressure of 120 mm of mercury, which was obtained by means of a rubber atomizer bulb connected through a 4 liter bottle. This bottle, which served as a pressure tank, was sufficiently large, so that the loss of a few cubic centimeters of fluid from the buret during the perfusion resulted in no appreciable change in pressure. These experiments were all performed on cats, decerebrated or under light ether anesthesia. Perfusion was always done through the femoral artery. The inflow cannula was placed in a side branch of the artery, or, which amounted to the same thing, low down on the main branch directed toward the heart. When a determination of the rate of inflow was to be made, a clip was momentarily placed high up on the main trunk, so that all the fluid had to pass through the capillary bed of the leg. A second clip, immediately in front of the cannula, was then removed, which allowed the perfusion fluid, usually from 2 to 3 c c, to pass into the vessels, the time being recorded with a stop watch. Immediately after the observation the upper clip was removed, thus allowing the part to receive its natural blood supply. Ether was administered by inhalation in the usual manner.

Before the ether was given, a number of determinations of perfusion rate were made in order to obtain the normal rate for the particular preparation. Ether was then given and the observations were continued, usually at intervals of about one minute as the animal became more deeply anesthetized. If etherization was pushed to an extreme, so that the second fall in pressure occurred, there was a sudden increase in perfusion rate, which was greater than that at the start. The constriction resulting from ether is well marked, for example, in one experiment on a decerebrated cat, the average perfusion time was three and one-tenth seconds for each cubic centimeter of fluid. This increased to ten and one-tenth seconds during the development of anesthesia, and gradu-

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65 Bartlett J Exper M 15 414, 1912

ally dropped back to the original rate after the ether was removed. A number of representative charts taken from these experiments are shown in Figures 12, 13 and 14. The fifth experiment was negative as far as any effect of ether on the perfusion rate was concerned, although the vasomotor center was active, as indicated by the rise in blood pressure resulting from asphyxia. Too much reliance, however, should

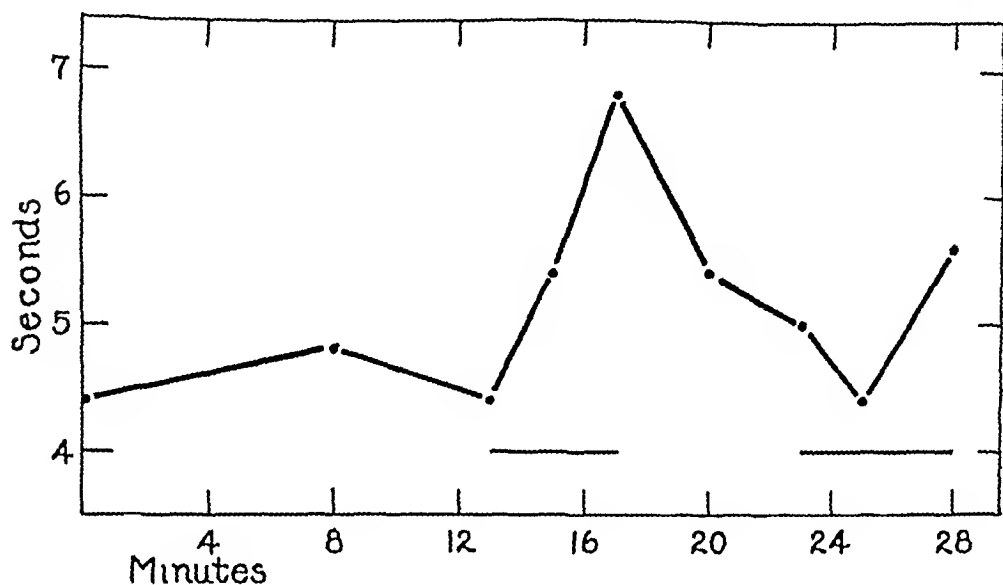


Fig 12—The effect of the inhalation of ether on the perfusion time of a fluid through the vessels in the hind leg of a cat. The horizontal line below the graph shows the period during which ether was administered.

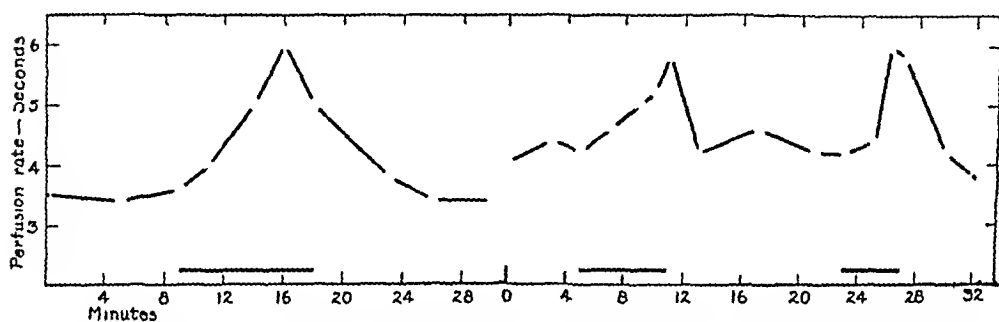


Fig 13—Same as Figure 12, the effect of ether on the perfusion time in two other animals.

not be placed on negative results, as the method involves considerable possibility of injuring the nerve supply to the leg through disturbance of the circulation. On the other hand, a decrease in perfusion rate during the administration of ether gives positive evidence of vasoconstriction. Two other animals failed to show any evidence of constriction under ether (Fig 17), but they also failed to show the usual recovery in blood pressure after the primary fall, and did not show an asphyxial

rise in blood pressure, thus giving the type of reaction found in shock. These experiments will be referred to later, in considering the condition of the vasomotor center in shock. The last two experiments of the series both showed a characteristic and well-marked constriction.

*The Effect of Ether Introduced Directly into the Circulation*—If the effect of ether on the heart is one of depression, and the effect on the vasomotor center one of stimulation, it should be possible to get

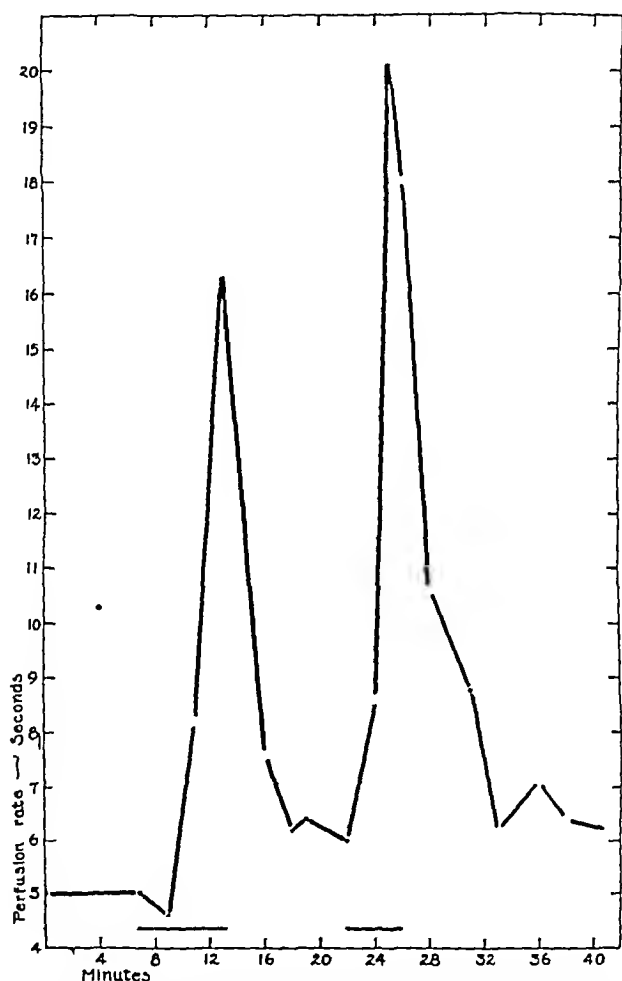


Fig 14—An extreme example of the increase in perfusion time during the administration of ether. The horizontal lines below the graph show the period during which ether was inhaled.

different effects on the blood pressure, depending on whether ether is injected into a vein, or into an artery toward the head. As previously mentioned, such methods have been used by other workers to obtain evidence on the place of action of anesthetics. In the course of the present investigation a number of such observations have been made, the injections of ether toward the heart being made through a cannula in the femoral vein and those toward the vasomotor center through

a cannula in the carotid artery. The most convenient method for introducing the ether was by means of a saturated solution in physiologic solution of sodium chlorid (approximately an 8 per cent solution at room temperature), which could be diluted to any desired strength.

The results from such injections show a definite and uniform difference. Figure 15 presents two examples of the different effects obtained

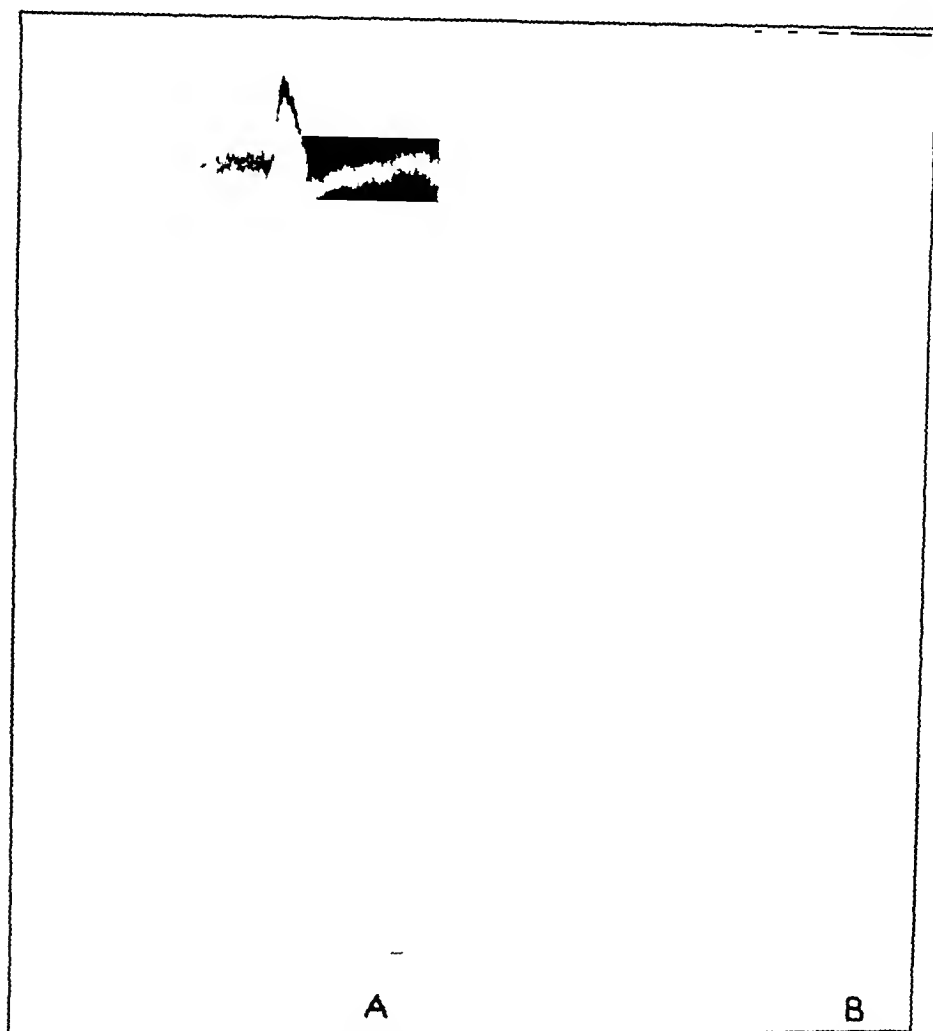


Fig 15—Records from two animals, for a comparison of the effect of injecting ether into the veins and into the arteries. In both records, the first pressure change is due to the injection of 0.5 cc. of a saturated solution of ether in physiologic solution of sodium chlorid into the femoral vein toward the heart, while the second pressure change is due to a similar injection into the carotid artery toward the head.

from the arterial and from the venous injection of ether, taken from two different animals. In each case, the first injection was made through the femoral vein, and the second into the carotid artery toward the brain. The effect of the arterial injection of the ether solution is an immediate

rise in blood pressure which in some cases is quite prolonged. Later there may be a temporary fall below the original level, which is presumably caused by an effect on the heart. This is shown in the second record of Figure 15. Physiologic solution of sodium chlorid containing no ether is absolutely without effect in such small amounts, but even with very dilute ether solutions, comparable to the concentrations found in the blood of anesthetized animals, there may be a considerable stimulation of the center, as indicated by the rise in blood pressure. Exactly

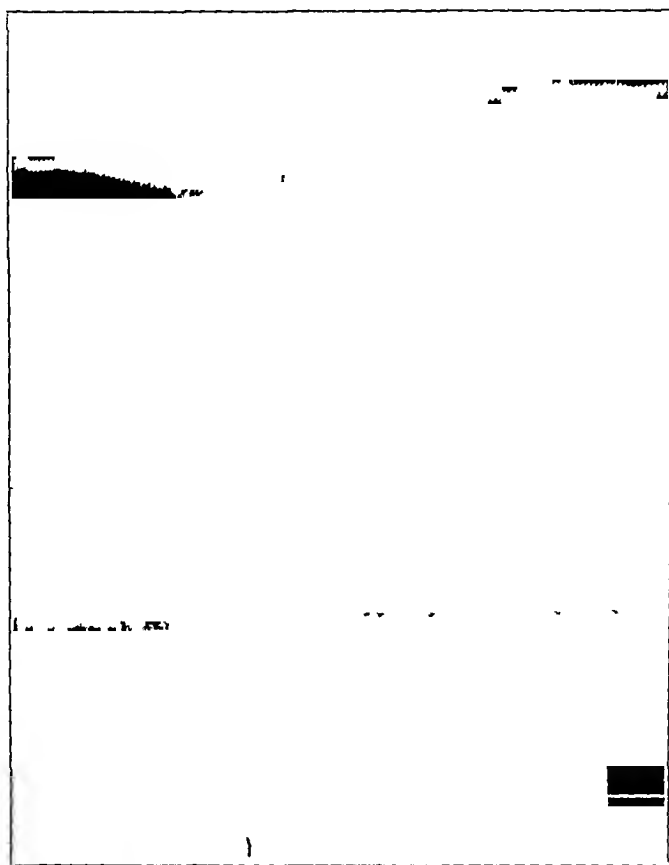


Fig 16—The effect of a first injection of 1 cc of a saturated solution of ether in physiologic solution of sodium chlorid into the femoral vein of a cat. Top record blood pressure with mercury manometer, bottom record zero blood pressure.

the opposite effect is obtained from the injection of the ether solution into the femoral vein. Here the heart is reached first and the effect is a definite though transitory drop in blood pressure. This may be followed by a gradual rise in pressure considerably above the original level, sometimes lasting for ten minutes or more. The first ether injection in a freshly prepared animal practically always induces such a rise following the primary fall (in twelve out of thirteen animals) but



later this does not occur. A tracing illustrating a typical example of this effect is shown in Figure 16. Since the injection of ether directly toward the brain causes a rise in blood pressure, it seems probable that this increase in pressure following the primary drop is also due to an influence of ether on the vasoconstrictor center.

*Deductions from Blood Pressure Changes*—The form of the blood pressure curve resulting from the administration of ether in the normal animal at once suggests that part of the effect is due to an influence on the vasomotor center. A typical record, as given in Figure 1, shows, after the primary drop, a recovery of the blood pressure, which takes place while the anesthetization of the animal is becoming deeper. Evidence has already been given that during this time there is a continuous weakening of the heart action, which would tend progressively to lower the blood pressure. If this is true the only assumption that will account for the recovery of the blood pressure during the inhalation of ether is an increased peripheral constriction. This, moreover, is a logical consequence of the drop in pressure resulting from a lessened heart output, quite apart from any direct stimulation of the vasomotor center. That the normal vasomotor reflexes are present even in deep anesthesia has been shown by Bowditch and Minot<sup>47</sup> and by Schemmerson.<sup>48</sup> While no special experiments have been made on the subject, it has been repeatedly observed in the course of this research that animals under deep anesthesia exhibit the usual vasomotor responses. This is further supported by the results of ether administration in shock, when it is found that in animals which do not exhibit vasomotor reactions there is also an absence of recovery of blood pressure.

*The Effect of Ether on the Peripheral Tone in the Shocked Animal*—The changes occurring from the effect of ether on the blood vessels and vasomotor system in shock can be discussed to better advantage after a consideration of the causes leading up to these changes. Here it will be sufficient to record only the experimental data obtained from the administration of ether in shock. It may be stated, however, that all the evidence indicates that the changes observed are referable to an abnormal condition of the vasomotor center, either an already existing maximum constriction of the blood vessels or a depression of the center.

The change which occurs in the blood pressure curve from the administration of ether in the shocked or "sensitive" animal has already been described. It is illustrated in the tracings shown in Figure 2. The fact that the primary fall is no longer followed by recovery suggests that the normal functioning of the vasomotor center has been impaired and that there is no compensation for the decreased activity of the heart, the pressure continuing to fall as the anesthesia deepens.

The extreme alterations in pressure produced by ether make the measurement of vascular changes very difficult. Plethysmograph records are unsatisfactory on account of the shrinking of leg volume resulting from the decreased pressure, making it practically impossible to judge whether constriction still occurs. In only one out of a number of experiments was it possible to get evidence on this point. Records from this case are shown in Figure 10. The first tracing shows the blood pressure and leg volume changes resulting from the administration of ether at the beginning of the experiment, and the second tracing, obtained under exactly similar conditions, shows the change produced after the development of shock. Here, after the animal has become sensitive to the ether, there is no indication of constriction, indeed,

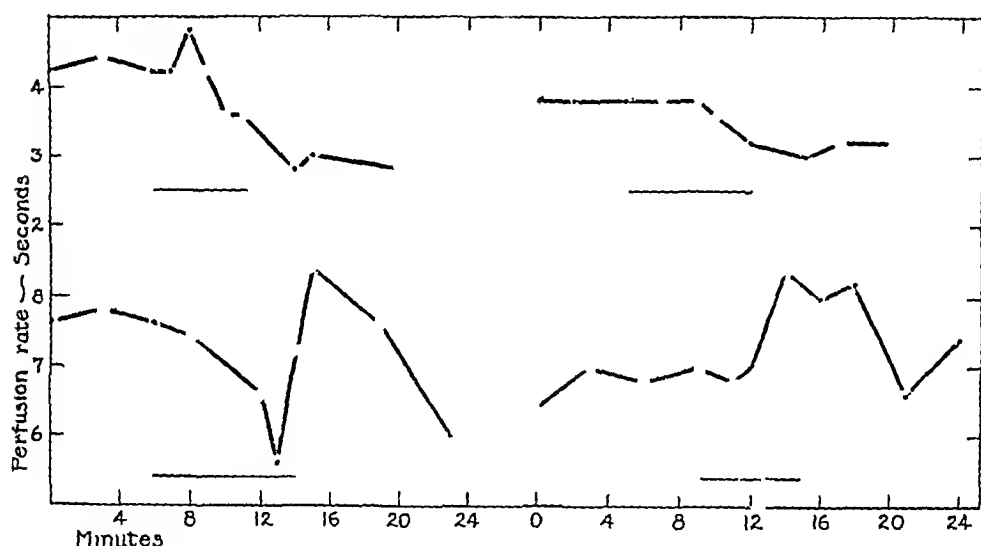


Fig 17—The absence of an effect, from ether, on the perfusion time in animals in a condition of shock. The horizontal lines below the graphs show the period during which ether was administered. Compare with Figures 12, 13 and 14.

there is probably some dilatation, since there is no decrease in leg volume associated with the very considerable drop in arterial pressure. A number of observations on this cat gave similar results.

Evidence obtained from perfusion of the hind legs in shocked animals has already been given. In these experiments, three cats gave no indication of a vasoconstriction during the administration of ether. Two of these animals showed a definite sensitivity to ether and failed to show any rise in blood pressure under asphyxia. Charts from these experiments are shown in Figure 17. Negative results of this nature must be accepted with caution. They are nevertheless recorded here as a further indication of the difference between the normal and the shocked animal.

There is a close comparison between the extent of the drop caused in the blood pressure curve by ether and the rise in blood pressure brought about by asphyxia the animals giving the greatest pressor response to asphyxia show the greatest resistance to ether. In an animal going into shock, these reciprocal changes occur simultaneously. Similarly, the rise in pressure caused by ether injected directly toward the brain is greater in the normal animal. It is from such observations as these that the main evidence must be obtained regarding the condition of the vasomotor center in the animal sensitive to ether. They will be discussed in greater detail after a consideration of the causes leading up to this ether "sensitiveness."

#### THE CAUSE AND DEVELOPMENT OF THE INCREASED SENSITIVENESS TO ETHER IN SHOCK

An examination of the different ways of inducing in an animal the condition in which ether so markedly affects the blood pressure throws further light on the probable cause of the condition. It is always associated with shock, and is gradually developed under any circumstances that depress the general bodily condition of the animal, especially low blood pressure. Severe operation, hemorrhage, the injection of acid into the circulation, all cause a marked increase in the ether effect, and these various agencies depress the circulation, appearing to do so by an effect on the vasomotor center or peripheral mechanism rather than on the heart. Experimental evidence has already been presented which indicates that the fall in blood pressure resulting from ether is brought about through an effect on the heart, and that this is normally compensated for, to a considerable extent, by a peripheral constriction mediated through the vasomotor system. In shock, this mechanism appears to be no longer functioning, with the result that ether causes a continuous drop in pressure as the depth of anesthesia is increased. The question arises as to what change has occurred in the circulatory control which in the normal animal prevents the drop in blood pressure. Two possible explanations suggest themselves. There is some evidence that the low blood pressure accompanying shock results in a depression of the vasomotor center so that it no longer reacts in the normal manner to a fall in pressure or other stimulus. Secondly, there is the possibility that in this condition of ether sensitivity there already exists a maximum contraction of the arterioles, so that there is no possibility of a further increase in the peripheral resistance to compensate for the lessened output of the heart.

*Production of Ether Sensitiveness by a Reduced Blood Pressure*—One of the simplest methods of producing shock and the associated ether sensitiveness is to interfere with the circulation so as to produce

a low blood pressure for a period of an hour or more. In these experiments, the routine method of bringing about the increased ether effect was that described in an earlier paper of this series,<sup>13</sup> in which there was an arrangement for increasing the intrapericardial pressure and thus preventing the normal return of the blood to the heart. Under artificial respiration, the thorax is entered between the ribs on one side at the level of the sternum, a small slit is cut in the pericardium and a glass cannula is tied in place. The thorax is now closed and the animal is allowed to breathe naturally. A small reservoir is connected with the cannula by means of rubber tubing and filled with physiologic solution of sodium chlorid or with 6 per cent gum acacia in this solution. By raising or lowering the reservoir, the heart can be subjected to varying pressures, and any desired arterial level can be produced and maintained. In a few experiments, the arterial pressure was regulated by compression of the heart by a clamp applied to the chest. This method gives similar results, but is inferior in that it interferes somewhat with the respiratory movements.

The reduction of the blood pressure by these means to 60 mm of mercury for one hour is practically always sufficient to cause a marked increase in the effects of ether on the pressure. In a very few cases, there was no such result, the reaction remaining much as it was before the pressure was reduced. Successive hours of this treatment served to increase still further the drop in pressure caused by ether. An example, taken from one of the earliest experiments carried out at Dijon, is shown in Figure 18. In this case, ether was administered by simply connecting the ether bottle with the tracheal cannula in a cat and allowing the animal to breathe through it until the eye reflex could no longer be elicited. Before a test for the effect of ether was made, all pressure was removed from the heart and the blood pressure was allowed to rise. Recovery was not usually complete, but depended on the length of time the pressure had been reduced.

*Production of Ether Sensitiveness by the Injection of Acid into the Circulation*—There are a few observations indicating that the simple injection of acid into the circulation will produce in an animal a condition in which the administration of ether results in a fall of blood pressure. In the course of a study made by the members of the Medical Research Committee of England to determine the influence of acidosis in the production of shock, it was noted that, after the injection of acid into the circulation of cats, they became exceedingly susceptible to the influence of anesthetics.<sup>25</sup> A few incidental observations made in the course of the present research confirm the findings of the British committee. That such treatment should affect the normal action of the

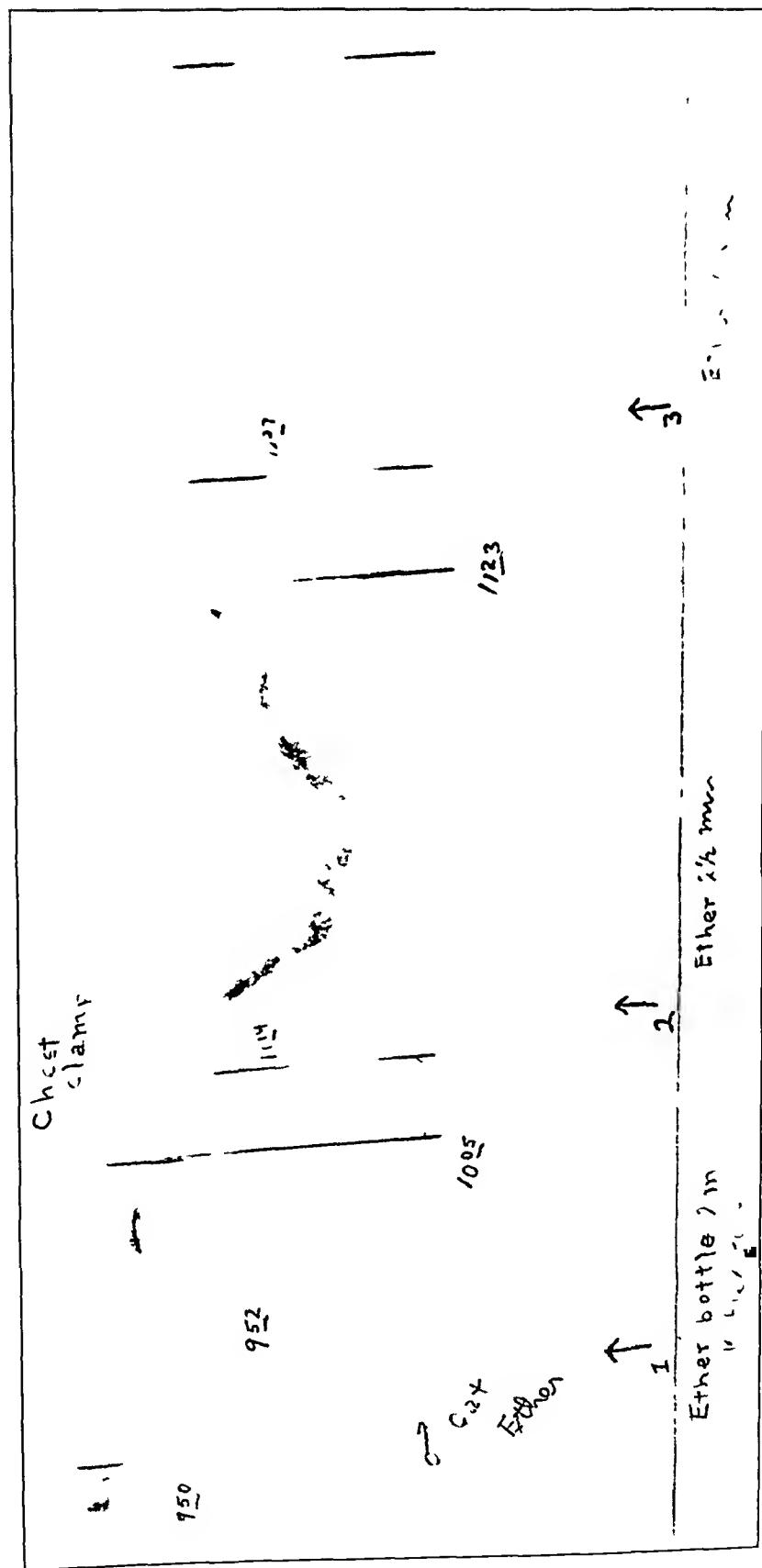


Fig 18—The development of ether sensitiveness from low blood pressure. Arrows mark the beginning of ether inhalation, which in each case was continued until the eye reflex just disappeared. 1, before reducing the blood pressure to 60 mm of mercury, 2, after one hour of low pressure, 3, after two hours of low pressure.

vasomotor center is not surprising. The increased hydrogen ion concentration would strongly stimulate the medullary centers,<sup>66</sup> causing a constriction of the peripheral vessels. Under these circumstances, it is to be expected that the delicate mechanism by which the vasomotor center normally responds to a fall in pressure would no longer be operative. There would thus exist a condition which, through the action of ether on the heart, would result in the continued fall in blood pressure.

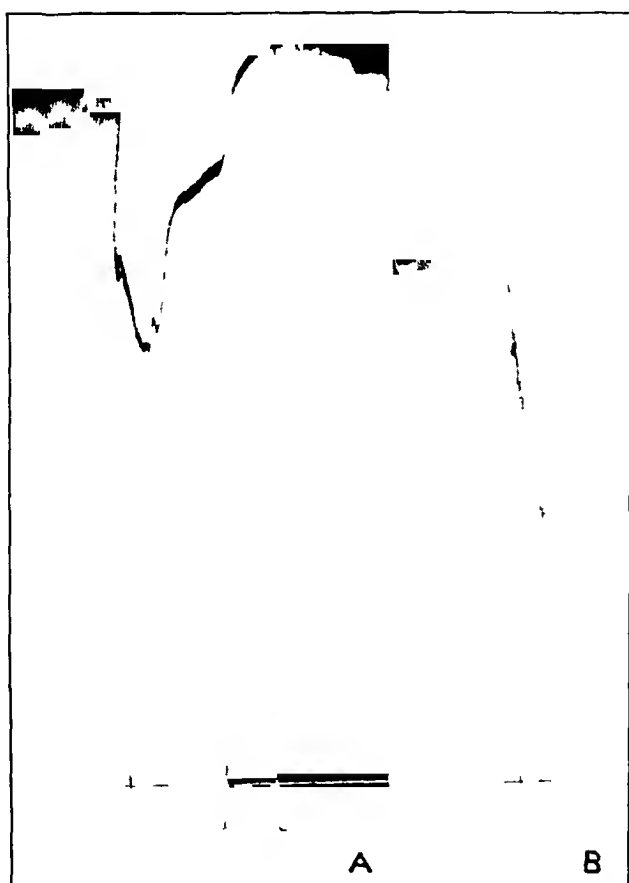


Fig 19—1, the effect of ether before hemorrhage, 2, after hemorrhage. In the first record, the administration of ether was continued for two minutes while in the second record it was administered for only one minute.

*Production of Ether Sensitiveness by Hemorrhage*—Another method by which increased sensitiveness to ether may be produced is bleeding. In a typical case if the animal is bled from 15 to 20 per cent of its total blood volume, there will be a recovery from the resulting drop of blood pressure within a few moments. Ether administered at this time will produce a marked drop in blood pressure similar to that produced in shock while before the bleeding no such drop resulted or

<sup>66</sup> Matheson. J. Physiol. 42: 283, 1911.

only a transitory one. Such an effect is shown in Figure 19. Under these circumstances, there must already be present at the time of the administration of ether, as shown by the recovery of the blood pressure following the hemorrhage, a strong peripheral constriction, and it is clear that, in this condition, there is less opportunity for a further reflex constriction to compensate for the reduced cardiac output, consequently, the ether effect shows itself in a greatly increased fall of arterial pressure.

Results such as these are the rule, but occasionally animals are encountered which show absolutely no increased sensitiveness to ether

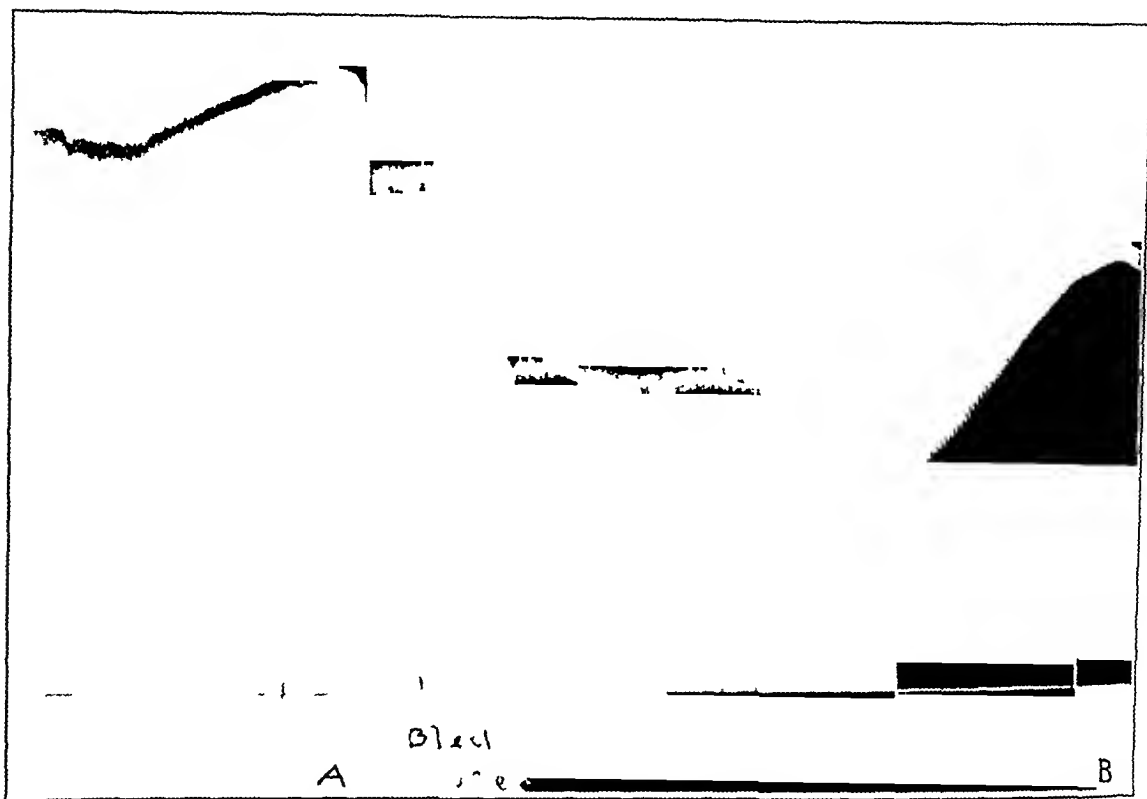


Fig 20—The effect of hemorrhage on the ether effect in an animal in which the pressure remained low after the removal of 22 cc of blood (weight of cat, 3.25 kg). Signal marks on base line (zero blood pressure) show duration of ether inhalation, which was for two and one-half minutes in each case.

after even a severe hemorrhage. In Figure 20, a tracing is shown from an experiment in which ether caused an actual increase of pressure when administered after bleeding. Two other animals gave results similar to the one shown in the illustration. In these animals, there was no reaction to the hemorrhage, that is, the pressure remained at the reduced level, perhaps indicating that there was no vasoconstriction. This gives a clue to a possible explanation. It is conceivable that, although the center did not respond naturally to the reduced pressure,

the ether in the blood was able to stimulate the center directly and that this caused a peripheral constriction, which, at this low level of blood pressure, was more than sufficient to compensate for the effect on the heart, with the result that the blood pressure was increased

*Production of Ether Sensitiveness by Other Causes*—As stated previously, there may be a gradual increase of the ether effect in animals which have not been specially treated to produce shock. This occurs after severe operations, such as decerebration and chest operations, and after long experimental procedures in which the animal has been kept under an anesthetic for several hours. It seems that any circumstances which tend to depress the general bodily condition of the animal cause, at the same time, this changed reaction toward ether. Undoubtedly, such conditions cause a certain amount of circulatory derangement in the direction of shock, and the vasomotor reactions become impaired. In general, a very close inverse relation exists between the rise in blood pressure resulting from asphyxia and the fall occurring from ether, the greater effect of ether being associated with a depression of the vasomotor reactions. This is true no matter by what method shock is produced, and, in animals which show absolutely no asphyxial rise, the effects of ether are always extreme. Occasionally, animals are found which exhibit a sensitiveness to ether from the very beginning of the experiment, but almost invariably such animals are in poor condition and have a low blood pressure.

#### COMMENT

The evidence presented in the preceding pages supports the supposition that the drop in pressure produced in the shocked animal is due to some disturbance of the vasomotor system. Since the causes of shock are not well understood and there is no agreement among the physiologists regarding the condition of the medullary centers in this condition, it is not possible to define, with any degree of certainty, the cause of the changed reaction to ether occurring during the development of shock. Determinations of the alkaline reserve made in this laboratory<sup>13</sup> indicate that the reduction of the blood pressure below 70 mm of mercury by means of intrapericardial pressure is sufficient to result in an inadequate oxygen supply to the tissues, and it is probable that this is followed by a depression of the nerve centers. That this is true for the vasomotor system is indicated by the fact that the longer the pressure is kept at such a low level the less pronounced the recovery will be after removal of the pressure on the heart. Moreover animals which have been treated in this way show no or very little response to asphyxia. But this cannot be the whole explanation. The forced reduction of the blood pressure would undoubtedly call forth a reflex or asphyxial stimulation of the peripheral vessels which would probably



be maximum. Indeed, it has been shown by Erlanger, Gesell and Gasser,<sup>67</sup> in perfusion experiments, that there is such a constriction in the similar condition brought about by occlusion of the vena cava. Both factors might be of importance, a depression of the vasomotor center possibly resulting from the continued stimulation and from oxygen deficiency, while at the same time the tone of the center would be maximum for its condition at any moment. With prolonged low pressure, the center would finally become unresponsive and the original constriction would give way to dilatation. This, in fact, was the case in Erlanger's experiments with occluded aorta, and in experiments carried out in this laboratory with muscle injury shock.<sup>68</sup>

This increase of the effect of ether in shock does not apply to ether injected directly into the circulation in small amounts, but is true only for the inhalation experiments, when a general anesthesia is produced. Numerous observations have failed to show any considerable increase of the drop in arterial pressure brought about by the injection of small amounts of ether dissolved in physiologic solution of sodium chloride, even when the animal has become markedly sensitive to the effects of inhaled ether. In the light of the experiments showing that the drop is due to an effect on the heart, and in consideration of the very small transitory effect produced by such small injections this result is to be expected. When the ether is injected into a vein it reaches the heart in a relatively high concentration, which is sufficient to cause a drop in pressure, but this effect does not last more than a few seconds and there is an almost immediate recovery, without the possibility of bringing a compensatory vasoconstriction into action. If the blood pressure curve from injected ether in the normal animal is not modified by vasomotor influences, there is no reason why the ether effect should be modified by any change in the vasomotor center or peripheral vessels occurring in shock.

In a series of experiments<sup>68</sup> on the perfusion rate of fluid through the vessels of the hind leg of the cat during the development of muscle injury shock, it was found that, as the blood pressure fell, there was a gradually increasing constriction of the peripheral vessels, and there are in the literature many observations indicating that the centers, at least during the early stages of shock, are not depressed.<sup>68</sup> On this basis, it must be assumed that the increased effect of ether in shock is a consequence of the strong vascular contraction which exists in this condition, preventing the normal compensation for the depression of the heart, rather than of a similar condition showing itself from a paralysis

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67 Erlanger, I, Gesell, R, and Gasser, H S. *Am J Physiol* **49** 90 (June) 1919

68 Cattell. *Science*, **55** 434, 1922

of the center. A depression of the center, however, probably ultimately results as a secondary effect of the prolonged low blood pressure. Thus, either of these two changes in the condition of the center may play a part in the result. But in the present consideration of the cause of the changed effects of ether in shock it is perhaps better, with such evidence as we have at hand, not to attempt to define too closely the exact change which has occurred in the center. All the evidence indicates that there is some disturbance of the delicately balanced arrangement for the control of the vascular tone. Whether stimulation or depression of the center is concerned in this change, the effect is one which destroys the normal reactions to a decreased pressure.

There is another factor which may be a contributory cause in the fall in blood pressure resulting from the administration of ether in the shocked animal. The literature on the direct action of ether on the blood vessels gives no conclusive evidence that there is or that there is not an effect on peripheral tone. If ether causes relaxation of the musculature of the blood vessels, as might be expected from its depressive action on heart muscle, etc., it certainly does not show itself in the intact animal. But if, in the condition of shock, there is a depression of the vasomotor center, it is conceivable that such a direct dilating action might make itself felt, and thus contribute toward the fall in pressure.

In discussing the effects of ether in shock, it has been assumed that the depressive action of this substance on the heart is sufficient to account for the fall in pressure, but no evidence has been adduced to indicate whether or not there is a direct depressant action on the vasomotor center in this condition. In the normal animal, all the evidence indicates that there is no depressive action on any part of the vasomotor system or blood vessels. The rise in blood pressure associated with a depression of the heart shows that there is stimulation of these parts of the circulatory system. The removal of this compensatory factor for the decreased heart output in shock seems sufficient to account for the greater fall in pressure resulting from ether anesthesia in this condition. Nevertheless, it is not inconceivable that, while in the normal animal ether results in a reflex stimulation of the center, in the shocked animal and after hemorrhage, when the center is already in a condition of maximum tone, it results in a gradual depression of the center, from its narcotic action.

#### SUMMARY AND CONCLUSIONS

1. In the normal animal, the inhalation of strong ether results in a sudden drop in the arterial pressure, which is quite temporary. As the anesthesia deepens, the pressure gradually recovers until by the time the eye reflex has disappeared it may have returned to its original level.

2 In the shocked animal, there is no recovery of the blood pressure after the primary fall and the pressure continues to fall to zero even before the eye reflex disappears

3 Nitrous oxid and oxygen in the most favorable proportions, can be administered to the shocked animal without causing more than a slight drop in blood pressure

4 Observations on the heart volume of intact cats, and on the contractions of the isolated cold-blooded heart, together with deductions from blood pressure records show that the administration of ether from its very beginning, results in a depression of the heart and a decrease in its output, which is sufficient to account for the fall in pressure in both the normal and the shocked animals

5 The injection of large doses of epinephrin intravenously in shocked animals usually results in the disappearance of the sensitiveness to ether for a period of an hour or more. Evidence is cited indicating that this is due to an antagonistic action of the ether on the heart. Pituitary extract does not influence the pressure drop produced by ether in the shocked animal

6 Determinations of leg volume with a plethysmograph, perfusion rate measurements, and results obtained by the injection of ether directly into the circulation, together with the form of the blood pressure curves, indicate that ether causes a contraction of the peripheral vessels. This constriction may be caused by (a) a direct stimulation of the vasomotor center and (b) a reflex to the fall in pressure resulting from a depression of the heart

7 In the blood pressure curves resulting from the administration of ether in the normal animal, the primary drop is probably due to an influence on the heart, and the subsequent recovery of the blood pressure, to a compensatory vasoconstriction

8 In the shocked animal, no evidence of a vasoconstriction produced by ether was obtained, and pressor effects from asphyxia or sensory nerve stimulation become less or are entirely absent

9 The condition of ether sensitiveness is brought about by any circumstances which tend to depress the general condition of the animal, such as low blood pressure, hemorrhage, severe operations or the injection of acid into the circulation

10 The cause of the greater depressing influence of ether on the blood pressure in shock appears to be due to a disturbance of the vasomotor system. The usual compensatory constriction no longer occurs to offset the decreased output of the heart, and the pressure continues to fall. This might be due to a depression of the vasomotor center or to an already existing maximum tone of the center so that there could be no compensation

# THE ROENTGENOLOGIC ASPECT OF CHRONIC APPENDICITIS

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Much has been written during the last ten years on the roentgen-ray examination of the appendix. The views expressed by the various writers in this time, excluding a certain amount of overenthusiasm, have differed only in minor details and in the exact dependence to be placed on some of the observations made concerning pathologic conditions of this structure and of the surrounding organs. The value of the roentgenologic examination in connection with appendicitis may be discussed under the following heads: (1) congenital anomalies in position, (2) data obtainable from observation of the visualized appendix, (3) abnormal appearances in other structures suggesting appendiceal origin when the appendix is not visualized, (4) the finding of some other condition than appendicitis to account for the symptomatology, (5) the finding of some other condition accompanying appendicitis and requiring further surgical exploration, and the exclusion of any other surgical condition than a diseased appendix thereby avoiding further exploration.

## VALUE OF ROENTGENOLOGIC EXAMINATION IN CONNECTION WITH APPENDICITIS

Practically all that can be said on this subject is a consideration of the possibilities of detecting a chronically diseased appendix or the results of previous inflammatory disease by means of a roentgen-ray examination. In only rare instances is it necessary or wise to submit a case of acute appendicitis to a roentgenologic gastro-intestinal study, and certainly never is it necessary when a correct diagnosis has been made.

1 The only congenital anomalies which need consideration are transposition of viscera in which case the cecum and the appendix if visualized will be found on the left side, and failure of complete rotation of the cecum, when the demonstration of the anomalous positions of the bowel may be of help in diagnosis and of assistance to the surgeon at operation.

2 Much valuable data may be obtained when the appendix is visualized. Unfortunately this does not occur in every instance in which a gastro-intestinal study is made. The exact proportion varies

considerably with different observers. Visualization depends on the patency of the lumen to the barium or bismuth taken with the opaque meal. It seldom occurs during an opaque enema. At first, visualization was regarded as evidence of disease, but this view was soon discarded. Conversely, the lack of filling of the appendix has been regarded as the result of obliteration of the lumen through disease. Naturally such obliteration prevents filling, but it is not to be expected that every normal appendix will fill with contents of the cecum at all times. Our dependence on observation of the visualized appendix lumen must be limited to a certain proportion of cases. The study of the visualized structure must be mainly fluoroscopic, although plates must be made, but when they are, it must be done under fluoroscopic control, as the shadow is so frequently hidden by other portions of the barium filled bowel. The diagnosis of disease is based on many appearances. Adhesions to the cecum, pelvic colon, ileum or other structures must be determined from fixation detected by the use of the palpating spoon. A kink that cannot be straightened or that tends to recur after straightening is good evidence of adhesions. A sharp kink may prevent filling of the entire lumen. The length and position and the caliber of the lumen are readily determined when the structure is visualized throughout. The relation between disease and irregular filling is one concerning which there is still some dispute. To ascribe the appearance invariably to constrictions arising from inflammatory thickening or cicatricial contractions cannot be exact, although it may be a correct interpretation in many instances.

The emptying time of a visualized appendix is an important observation. If the opaque contents remain after they have left the cecum, poor drainage is a correct inference. This in itself cannot be regarded as evidence of disease except so far as a poorly draining appendix can be regarded as a diseased appendix, or potentially so.

One of the most important observations to be made is the relation of the visualized appendix to pain on pressure. Naturally, more or less discomfort is usually experienced when firm pressure is exerted over the appendix or cecum, but when exquisite tenderness is experienced when the pressure is exerted directly over the appendix, especially when the pain is constant when the structure is moved from place to place, and there is little discomfort from firm palpation elsewhere in the immediate neighborhood, this finding is of considerable value, and must be of greater accuracy than a similar clinical finding when the exact location of a structure which is variable is unknown. Even if the appendix is not visualized, the roentgen ray always reveals its probable relation to the tip of the cecum, and tenderness at this point is always suggestive. One must be careful not to mistake tenderness due to a diseased appendix for that due to pressure on a ptosed kidney,

or over an inflamed tube or ovary in the case of a low lying cecum. In fact, it is wise to have clinical data furnished by a pelvic examination before interpreting tenderness over an appendix, in the case of a low cecum, as possible evidence of appendicitis. Patients are frequently found with extreme hyperesthesia of the skin, whereas if deep pressure is exerted when they are off their guard, the hyperesthesia may be differentiated from appendiceal tenderness.

A retrocecal appendix may be found by pushing out of the way a more or less movable cecum, but when the appendix is adherent or the cecum fixed, it may not be seen until the cecum is empty, or nearly so, of opaque contents. Whenever a retrocecal appendix is suspected because of its absence elsewhere and the evidence of adhesions or continued tenderness over the cecum, it is wise to continue the examination until the latter is empty. The finding of a retrocecal appendix is always an important one, but its significance in connection with the clinical aspect of the case must be carefully considered with the clinician and surgeon. Certainly, if it is long, fixed and pointing upward in a case with symptoms referable to the right upper quadrant, the value of such an observation may be very great.

The presence of fecal concretions or opaque foreign bodies, such as pins, in the appendix is obviously an important finding. It is probable that a small inspissated fecal mass will not show unless it becomes barium covered by the opaque meal, or calcium covered through the inflammatory process present or induced by the foreign body. It is, of course, most important that the shadow of a fecal concretion be accurately differentiated from a ureteral stone.

3 When the appendix is not visualized, the presence of disease must be indirectly inferred from abnormal appearances observed in connection with other structures, and it is quite possible for the organ to be diseased without any manifestations elsewhere. The most important finding is the presence of adhesions, especially in connection with the terminal ileum. If this structure is kinked or adherent to the cecum, the origin of such adhesions, in the absence of pelvic inflammatory disease, is probably the appendix. Occasionally, the pelvic colon will be found adherent to the cecum or drawn over to the right iliac fossa and fixed there. Ileac stasis alone, or contents in the terminal ileum eighteen hours or longer after ingestion of the meal, provided the gastric motility is not delayed, may be an evidence of a diseased appendix, but it cannot be safely regarded as a diagnostic sign, and is not very reliable. Continued exquisite tenderness at the tip or lower inner border of the cecum when the appendix is not visualized is a sign of considerable importance, but, of course, it does not possess the same value as the visible relation between the visualized structure and the tender point.

Definite pyloric spasm is an evidence of appendiceal trouble that should not be overlooked. It is by no means always present, but when observed, and not of such intensity as to suggest an intragastric cause, the right iliac fossa should receive a most careful examination. A cause may, of course, be found higher up, such as a diseased gallbladder or gallstones, which may sometimes produce pyloric spasm.

4 That there are many conditions the symptoms of which may more closely simulate those of chronic appendicitis is shown by the frequency with which the roentgenologist is called on to examine for other conditions before the clinician or the surgeon is willing definitely to conclude that the symptomatology is appendiceal in origin. Ureteral stone seems to be the most frequent condition to be excluded. Next in frequency seems to be gallbladder disease and gastric and duodenal ulcer in the upper abdomen. Other conditions which may cause symptoms more or less confusing in the diagnosis are diverticulitis of the colon, inflamed Meckel's diverticulum, early malignancy of the bowel, tuberculosis of the cecum and disease of the spine. Colonic diverticula are easily found, but Meckel's diverticulum is very difficult to detect. Malignant disease is usually demonstrated readily, but early malignancy may be overlooked unless the examiner is on the lookout for it. Tuberculous colitis has been diagnosed frequently, but may be mistaken for malignancy or adhesions. Pelvic conditions, such as ovarian or tubal disease or ectopic pregnancy, are rather beyond the pale of roentgenology as a rule.

An examination of the chest by fluoroscope at least should be a part of the routine gastro-intestinal study. Sometimes an adherent or restricted diaphragm will point to a previous pneumonia and pleurisy which were accountable for the supposed abdominal symptoms. We recently found, in a case with obscure lower abdominal pain of long standing, a very much elevated and fixed right diaphragm without enlarged liver or cause above for the phenomena, and which was probably due, therefore, to a previous subphrenic abscess. These findings brought the appendix under suspicion as a possible cause.

5 The frequent coexistence of a diseased appendix and some other surgical condition of the abdomen, such as gallbladder disease, gastric or duodenal ulcer, kidney stone and many others, is well recognized. It would be too great a burden for the roentgenologist to make a routine gastro-intestinal study in every case of appendicitis unless his work was largely confined to that particular field. If, however, the symptomatology is in the least obscure or some other condition is suspected elsewhere in addition, a complete study is likely to justify the surgeon in limiting his exploration to the region of the appendix if no other condition is found, or to direct him to the proper field if a coexisting surgical condition is demonstrated.

# THE RELATION OF THE HEART, PERICARDIUM AND THE HEART VALVES TO THE ANTERIOR CHEST WALL

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In the past the descriptions of the usual relationship of the heart and its valves to the chest wall, in the works on anatomy, have been based upon dissections. These have been supplemented in some cases by the insertion of needles in order that the relationship between the surface and the deeper structures might be retained. That this method was not accurate is evidenced by the great variations in the location, for example, of the heart and its valves as reported by different anatomists.

For example, Gray<sup>1</sup> gives the following description of the heart:

The base looks upward, backward and to the right and is separated from the fifth, sixth, seventh and eighth thoracic vertebrae by the pericardium, esophagus, aorta and thoracic duct.

The apex formed by the left ventricle is directed downward, forward and to the left, and is overlapped by the left lung and pleura, it lies behind the fifth left intercostal space, about 8 cm from the midsternal line, or, in the male, about 4 cm below and 2 cm to the medial side of the left mammary papilla.

The sternocostal surface is directed forward, upward and to the left. It consists of an atrial and ventricular portion, the former being above and to the right, the latter below and to the left of the anterior part of the coronary sulcus. The sternocostal surface lies behind the body of the sternum, the transverse thoracic muscles and the cartilages of the third, fourth, fifth and sixth ribs, owing to the bulging of the heart toward the left side, a much greater part of the surface lies behind the left than the right cartilages. The sternocostal surface is also covered by the pleura and the thin anterior part of the lungs, with the exception of a small triangular area corresponding with the cardiac notch in the left lung. The base of this triangular area is represented by a line on the middle of the sternum from the level of the fourth costal cartilages to the junction of the body of the sternum with the xiphoid process, and the sides by lines from the apex of the heart to the upper and lower ends of the base line.

The right margin of the heart, formed by the right atrium, is rounded almost vertical. It is situated behind the third, fourth and fifth right costal cartilages, about 1.25 cm from the margin of the sternum.

The inferior and acute margin formed almost entirely by the right ventricle is nearly horizontal and extends from the sternal end of the sixth costal cartilage to the apex of the heart.

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<sup>1</sup> Gray, Henry. Anatomy—Descriptive and Applied, Ed 21, Philadelphia, Lea & Febiger, 1921.



The left and obtuse margin is full and rounded, it is formed, mainly, by the left ventricle, but to a slight extent above, by the left auricle. It extends from a point in the second intercostal space, about 2.5 cm. from the sternal margin obliquely downwards, with a convexity to the left, to the apex of the heart.

According to Piersol<sup>2</sup>

The heart may vary considerably in position without being regarded as abnormal, but what may be considered its typical position with reference to the anterior thoracic wall may be stated about as follows. The apex is situated

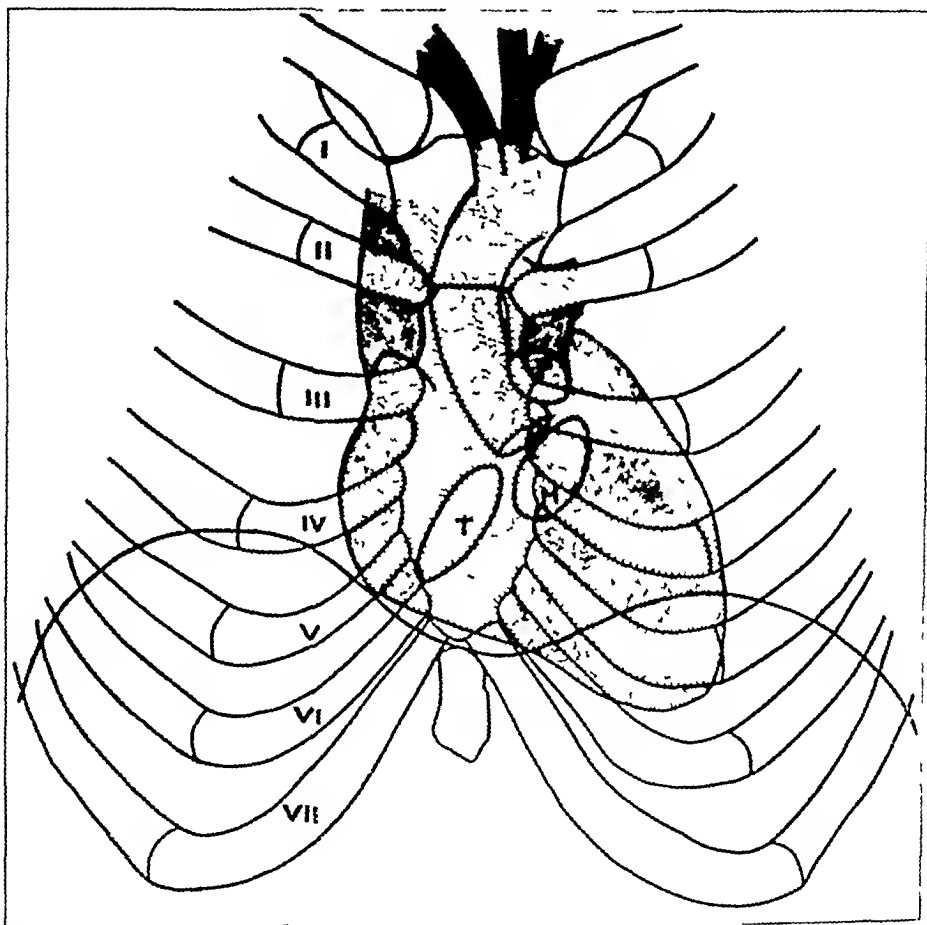


Fig 1—Outline drawing of teleroentgenogram (Fig 2) and stereoscopic roentgenograms. The position of the valves *T* (tricuspid), *M* (mitral) and *P* (pulmonary) may be noted. The aortic valve is indicated by the beginning of the aorta.

behind the fifth intercostal space, about 8 cm. (3¼ inches) from the median line, this position being median to and slightly below the junction of the fifth costal cartilage with its rib. The level of the base may be approximately indicated by a line drawn from a point slightly above the upper border of the third costal cartilage of the left side, about 4.5 cm. (1¾ inches) from the

<sup>2</sup> Piersol, G. A. Human Anatomy, Philadelphia, J. B. Lippincott Company, 1907, p. 692.

median line of the sternum, to a point on the upper border of the third costal cartilage of the right side, about 3 cm ( $1\frac{1}{4}$  inches) from the middle line. If now the left end of the base line be united to the apex point by a line which is slightly convex toward the left, and a line, markedly convex toward the right, be drawn from the right end of the base line to the junction of the seventh costal cartilage of the right side with the sternum and thence to the apex point, a heart area will be enclosed which corresponds to the outline of the organ as seen from in front.



Fig 2—Relationship of the heart and its valves to the anterior thoracic wall. Compare Figure 1, exposure made at a distance of 6 feet (18 meters), measurements verified later by dissection.

Considerable importance attaches to the location of the auriculoventricular and the aortic orifices with reference to the anterior thoracic wall. The right auriculoventricular orifice in a typical heart lies on a level with the attachment of the fifth costal cartilages to the sternum, almost behind the median line of that bone and opposite the fourth intercostal space, while the left auriculoventricular orifice is opposite the sternal end of the left third intercostal space. In other words, these openings lie along a line which corresponds with the auriculoventricular groove, and this may be represented by a line drawn from the upper border of the junction of the seventh costal cartilage of the right

side with the sternum to the sternal end of the third left costal cartilage. The right orifice is located upon the line where it is intersected by a line joining the sternal ends of the fifth costal cartilages while the left one is situated at its upper end.

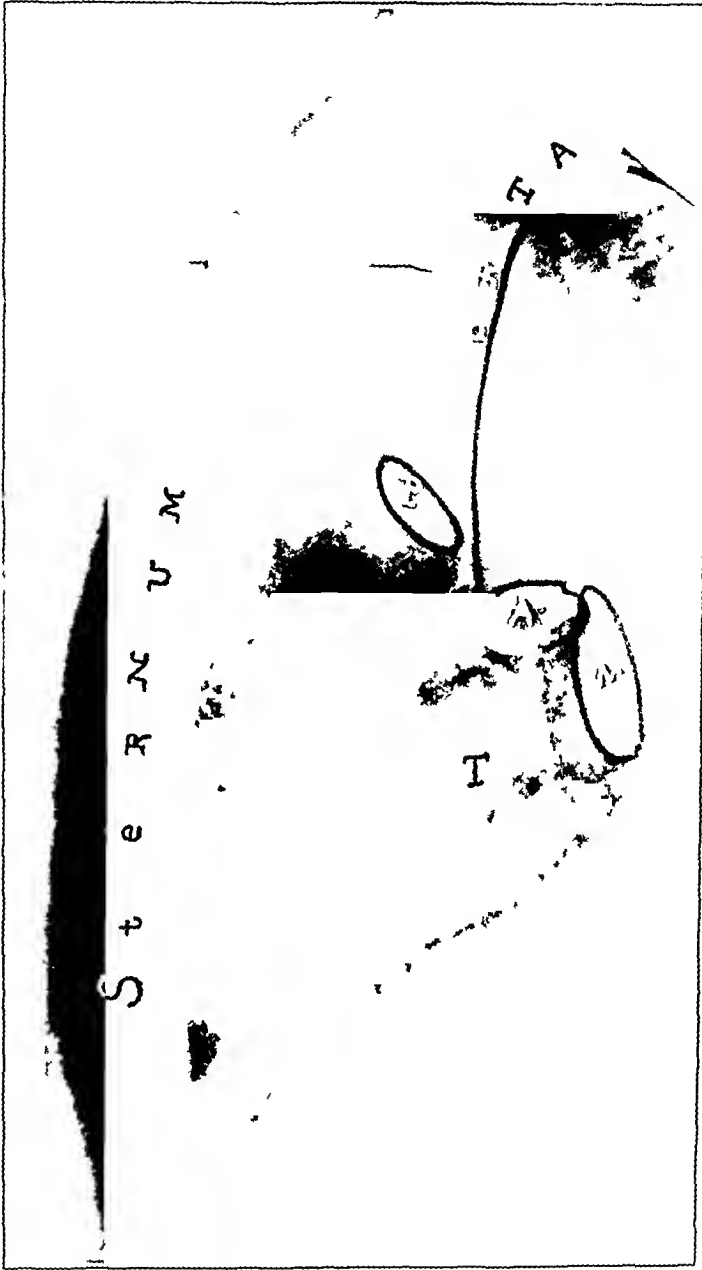


Fig 3—Lateral exposure showing the depth of the valves *P* (pulmonary), *T* (tricuspid), *A* (aortic), *M* (mitral)

The systemic and pulmonary aortic orifices are situated at about the level of the attachment of the third costal cartilages to the sternum, the pulmonary orifice being behind the sternal end of the third left cartilage, while the aortic orifice is behind the left half of the sternum a little below and to the right of the pulmonary one, the two orifices overlapping for about one quarter of their

diameters. It is to be noted, however, that the pulmonary aorta is directed upward and to the left, while the systemic aorta inclines decidedly toward the right in the first part of its course and since the sounds caused by the valves which guard the orifices are carried in the direction of the blood stream, auscultation of the pulmonary semilunar valves may be practised over the sternal end of the second left intercostal space while that of the systemic valves is best performed over the sternal end of the second right space.

Similarly the close proximity of the areas of the left auriculoventricular and systemic aortic orifices, as projected upon the thoracic wall, might lead to confusion, were it not that the course of the blood passing through the two orifices is in opposite directions, and the auscultation of the auriculoventricular orifice is consequently satisfactorily performed toward the apex of the heart.

Considerable variation from the position of the heart indicated above, may be found. Thus the apex may be situated behind the fifth costal cartilage, or

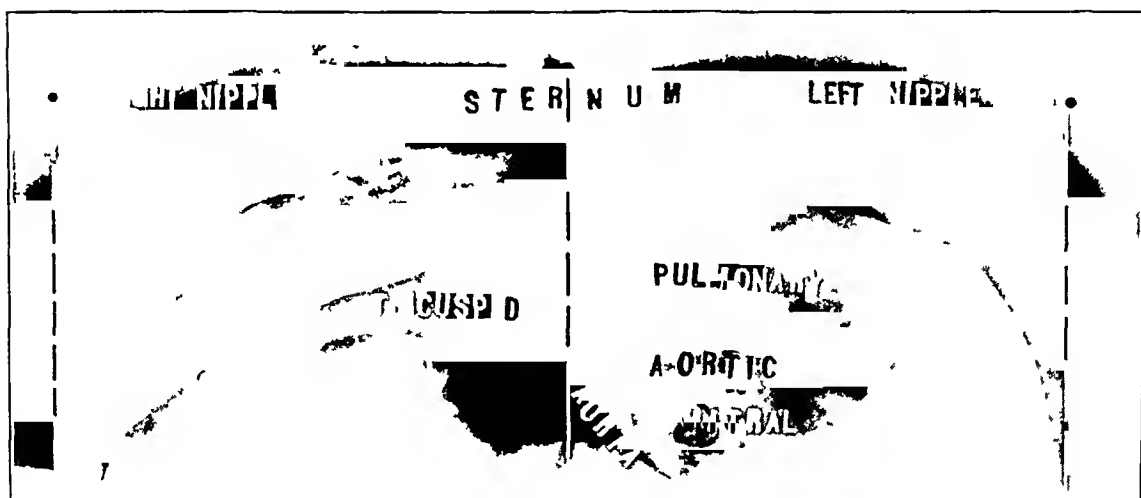


Fig 4—Vertical projection showing relationship of valves to median line of the body

more rarely the sixth, and the pulmonary aortic orifice may occur as high up as the second intercostal space, or as low as the level of the fourth costal cartilage.

The heart naturally has its position altered somewhat during its contraction and during the respiratory acts, and the position of the body will also have some effect in modifying its location. Resting as it does upon the diaphragm, the heart will alter its position somewhat with alterations of that muscle, and since in the child the diaphragm is somewhat higher and in the aged somewhat lower than in the middle period of life corresponding changes according to age will be found in the position of the heart. It may be noted furthermore, that the position of the heart as determined in the cadaver will, as a rule, be slightly higher than in the living body, owing to postmortem tissue changes which allow the diaphragm to assume a more vaulted form than is usual in life.

In only one instance have two observers agreed. On further study, this agreement was found to be due to the fact that the data had been transferred from one author to another with due credit.

NEW METHOD OF DETERMINING THE RELATION OF THE  
HEART AND ITS VALVES

In view of the facts above stated, it was decided, at the suggestion of Dr H D Senior, Professor of Anatomy at Bellevue Hospital Medical College, to attempt a new method. This was accomplished and the results published in Morris' Anatomy and in the Stereo Atlas. The

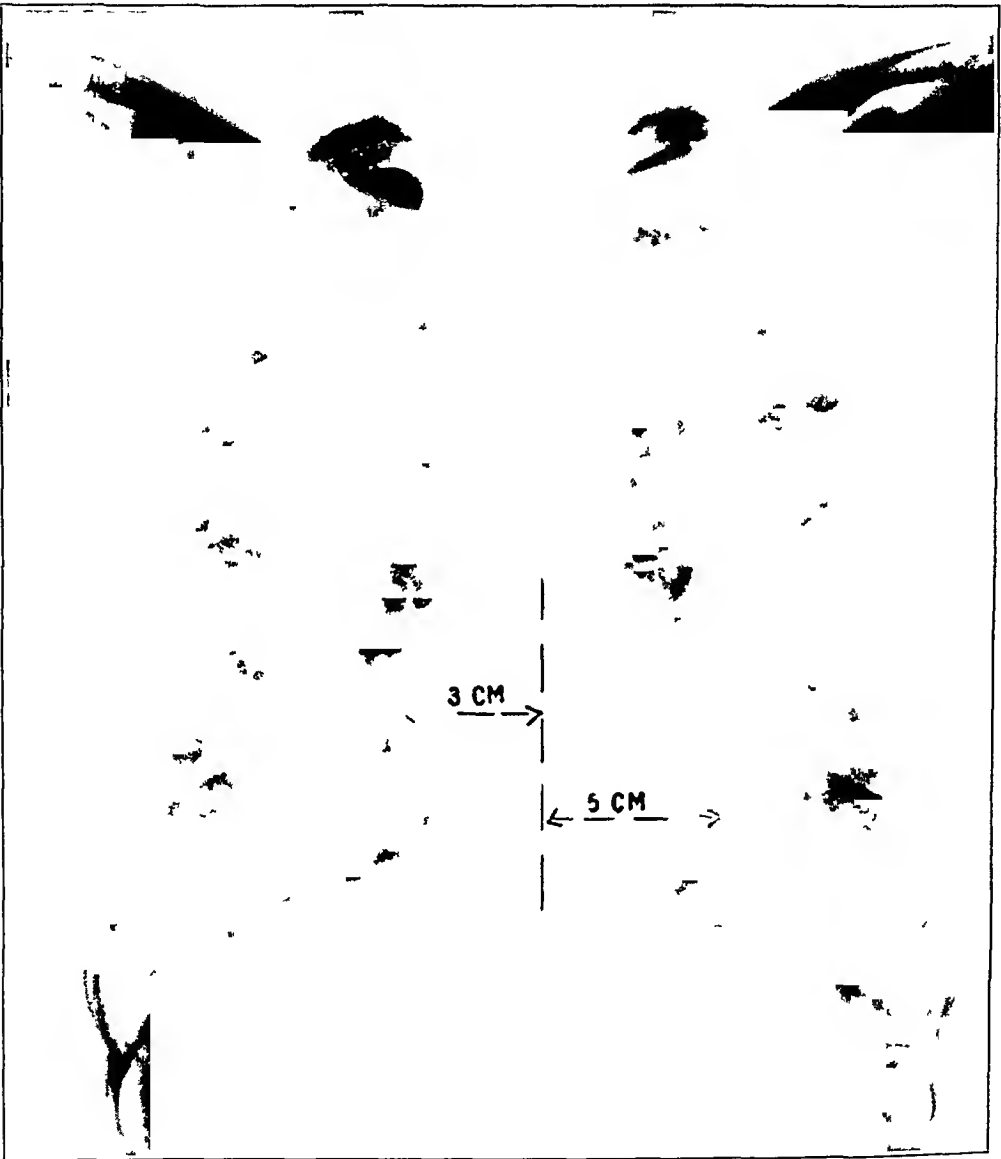


Fig 5—Hypoplasia of the heart, the extremely small size of the heart, the transverse diameter being only 8 cm, may be noted

body was injected through the right carotid artery with equal parts of commercial liquor formaldehydi and water, the injection being begun with the body in the horizontal position and finished with the body in the vertical position. The body, which had been stored in the

horizontal position for some months, was frozen and the thorax removed. The frozen thorax was then cut accurately, by means of a band saw, in the frontal plane so as to open both auricles from behind, without interfering with the contour of the heart. In the intact interior portion of the thorax, the mitral and tricuspid valves were readily accessible. Wires were bent so as to fit accurately the groove corresponding to the attachment of the valves to the heart wall. The wires were placed in position from the auricle, and, in the case of the

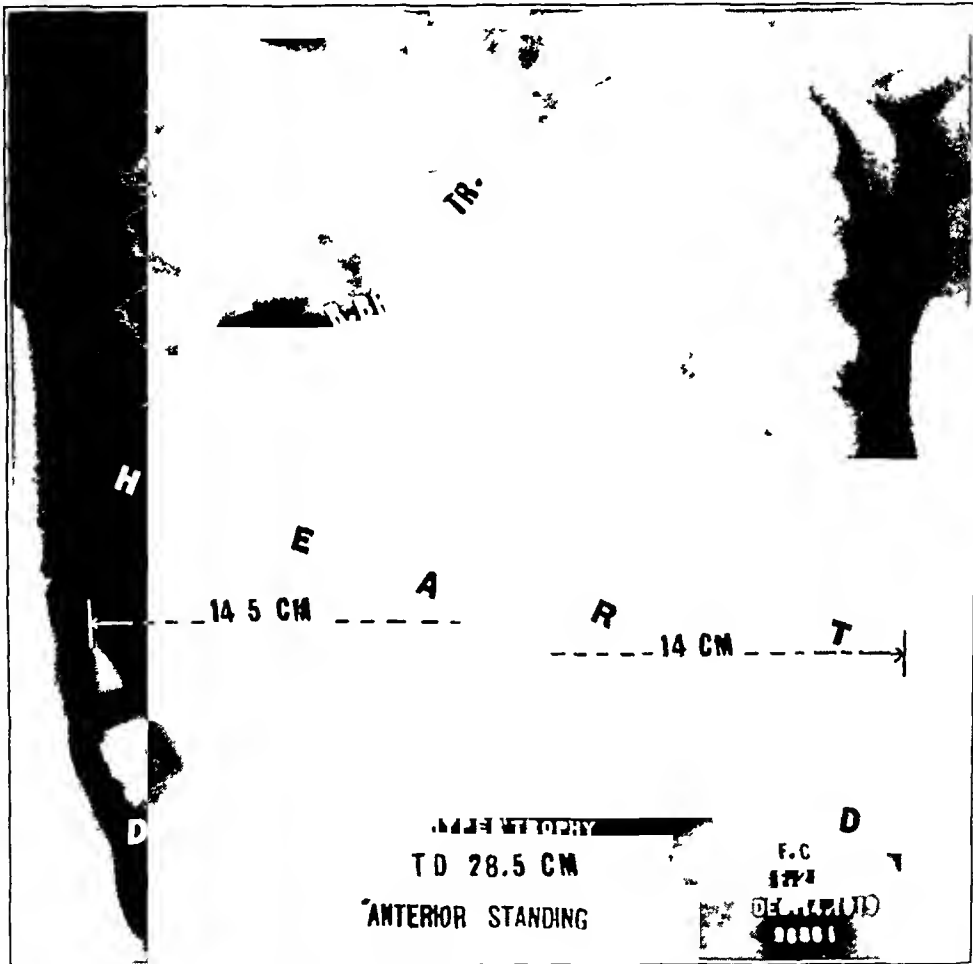


Fig 6—Hypertrophy of the heart (transverse diameter, 28.5 cm) which could be mistaken for pericardial effusion (Fig 8), the narrowing at the great vessels may be noted. Patient under observation for six years, had rheumatic fever at age of 7, aged 28 at time of this roentgenogram.

tricuspid valve, fixed by means of two sutures. The cusps of both auriculoventricular valves were found to be in apposition. The interior of the aorta was reached through the anterior wall of the left auricle. The region of the pulmonary valve was made accessible by removing the remainder of the left lung and cutting the artery longitudinally.

from the left side. Wires were shaped to fit the aortic and pulmonary orifices and placed so that they were in contact with the deepest part of each of the semilunar valve cusps, which provided excellent guides in placing the wires. After placing the pulmonary ring the cut edges of the vessel came into position. The accuracy of the position of the wires was verified after roentgenograms had been taken.

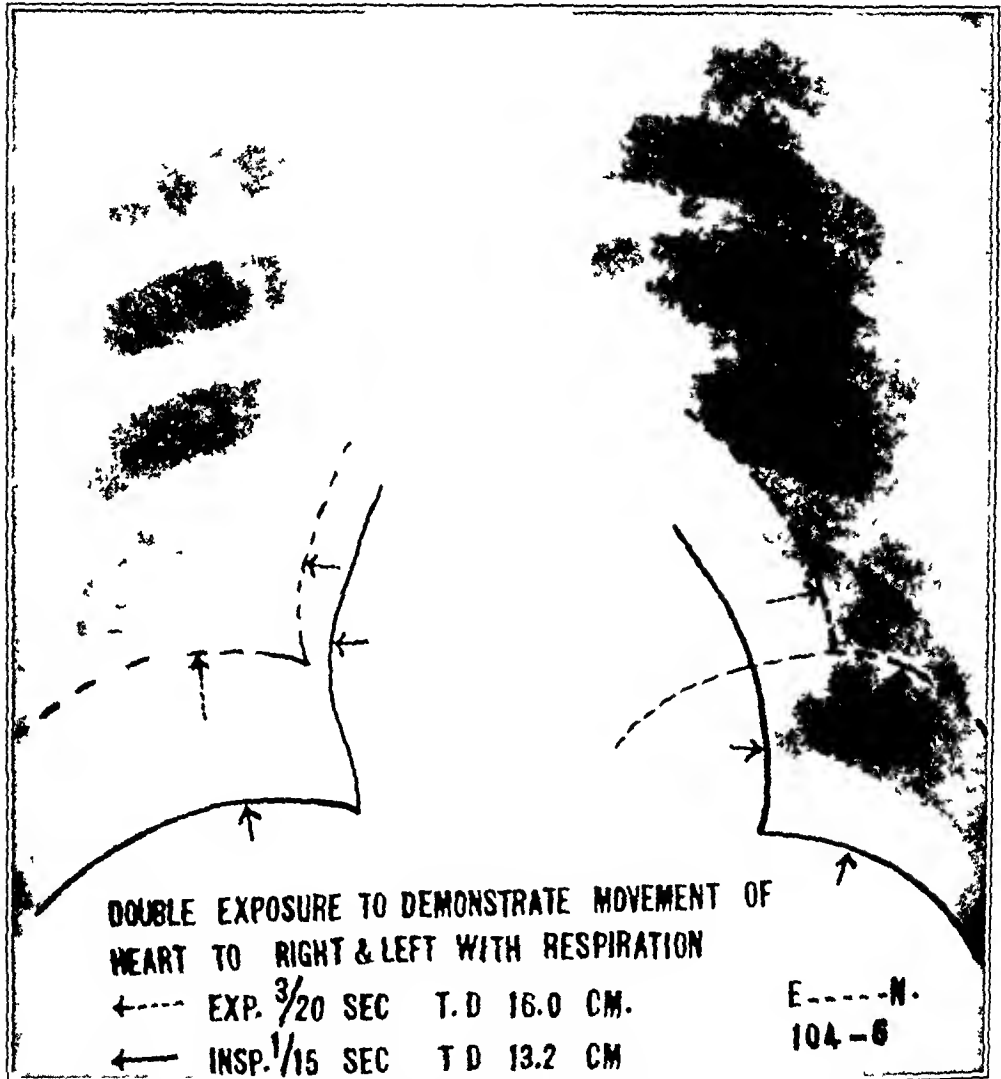


Fig 7—The aviator's heart, showing the effect of respiration on the heart solid line indicates diaphragm and heart at full inspiration, broken line indicates diaphragm and heart at full expiration (difference in transverse diameters, 28 cm.) Two exposures were made on one plate to demonstrate the change in size and position of the heart during deep breathing

The first teleoroentgenograms were taken with the material frozen, the remaining portions of the lungs and liver having been removed after freezing. The parts were so rigid, however, that after the first trials freezing was not repeated. It can safely be said that lack of

rigidity is not a source of error. To minimize optical distortion, the tube was placed 6 feet (1.8 meters) from the object, which was horizontal, with the anterior surface in contact with the plate holder. The tube was accurately centered on a spot, which may be distinguished in the roentgenogram a short distance above the tricuspid ring. The spot is embedded in the skin of the median line of the thorax at the middle of the longitudinal area occupied by the wires.



Fig 8—Pericardial effusion, the water bottle shape of the heart area, with the broadening at the great vessels, and obliteration of the usual curves, indicated by the arrow, may be noted.

Stereoroentgenograms were made in the usual way and the subject was also roentgenographed in various positions.

The outline drawing (Fig 1) was traced from the negative (Fig 2), most of the doubtful points in which were elucidated by the stereoscope. The left limit of the superior vena cava and a small portion of the upper left margin of the heart, where the picture of the latter is obscured by the root of the lungs, could not be determined with certainty. The



outline is omitted from these regions, but subsequent removal of the heart testified to the approximate accuracy of the dotted lines by which these margins are indicated. Several parts identified in the stereoroentgenogram have been omitted for the sake of clearness, such, for instance, as the inferior vena cava, and the anterior papillary muscles of the right and left ventricles, and one of the mitral cusps.



Fig 9—Calcified pericardium which may give little or no evidence on ordinary physical examination but is readily detected on roentgen-ray examination.

The apex is in the fifth intercostal space, from 7.5 to 8 cm (3 to  $3\frac{1}{4}$  inches) from the median line. The base (above) corresponds to an imaginary line (*A*), drawn from a point 1 cm ( $\frac{2}{5}$  inch) below the second left chondrosternal articulation, and 3 cm ( $1\frac{1}{5}$  inches)

from the median line to another point the same distance from the median line, 1 cm above the right chondrosternal articulation. The maigo acutus, or lower border, corresponds to a line (*B*) drawn from the apex through the xiphisternal articulation, to a point on the sixth costal cartilage, 2 cm to the right of the median line. The right border of the heart may be indicated approximately by an imaginary line (slightly convex to the right), joining the right ends of the *A* and *B*. The left border corresponds to a line (slightly convex to the left), joining the left end of *A* to the apex.

If a line is drawn from the upper margin of the left third chondrosternal articulation to the right edge of the sternum in the fifth intercostal space, the upper end of the line will lie over the center of the pulmonary orifice, and the lower two thirds of it (approximately) will overlie the main axis of the tricuspid orifice. The aortic orifice is immediately to the left of the above line, with its center at the left edge of the sternum, opposite the third space. The mitral orifice is very largely behind the third left interspace, its upper end is behind the third cartilage, its lower behind the left margin of the sternum, opposite the fourth cartilage and space.

Of the orifices of the heart, the pulmonary is the nearest to the anterior thoracic wall, the tricuspid is slightly in advance of the aortic, and the mitral deepest of all (Figs 3 and 4).

The pericardium follows the outline of the heart closely. The upper end (apex) in this subject extended up behind the sternum, to the lower margin of the first costal cartilage on the right and the upper margin of the second on the left.

The positions occupied by the cardiac orifices may be seen so plainly that it is unnecessary to describe them further. It may be said, however, that all the rings are seen from the lower (anterior) aspect except the aortic, which is seen from above.

Norris and Fetteroff<sup>3</sup> approached the study of the problem with the aid of horizontal sections and coated the heart valves with a lead preparation prior to making roentgenographic studies. This method, it seems to me, while valuable, disturbs the anterior chest wall. Groedel<sup>4</sup> roentgenographed the heart after it had been removed from the body and obtained valuable information in this way.

#### VALUE OF ROENTGENOGRAMS IN DIAGNOSIS

The accompanying roentgenograms are interesting in that they illustrate certain pathologic conditions. Hypoplasia of the heart has received comparatively little attention. While it is necessary always to

3 Norris, G. W., and Fetteroff, G. *Am J M Sc* **145** 225, 1913

4 Groedel, F. M. *Arch Roentgen Ray* **17** 86, 1912

take into account the size and type of the individual, yet several instances of hearts which were distinctly smaller than normal have been encountered (Fig 5)

In hypertrophy of the heart, the teleoroentgenogram is the best method of determining the amount of enlargement. When of extreme degree, the findings are easily determined (Fig 6). When the question of minor degrees of hypertrophy or gradual increase of the size of the heart is the question to be determined, extreme care in technic is necessary in order that the effect of respiration, displacement of the diaphragm, etc., may be taken into consideration. This problem was encountered in the study of the aviator's heart<sup>5</sup> (Fig 7). In pericardial effusion, the roentgenologic examination is of great importance, but the findings must be interpreted with great care (Fig 8). A case of calcified pericardium gave no physical signs indicative of the condition which was discovered on fluoroscopic examination (Fig 9). Prior to any surgical procedure involving the chest, a careful roentgenologic examination in various positions should always be made.

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5 Le Wald, L. T., and Turrell, Guy. The Aviator's Heart. Roentgen-Ray Studies Under Conditions Simulating High Altitudes, *Am J Roentgenology* 7: 67 (Feb.) 1920.

# THE VALUE OF PERICARDIOTOMY IN DIAGNOSIS AND TREATMENT \*

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PHILADELPHIA

Diagnosis may be established in obscure conditions occasionally, and permanent relief given to the patient, with only a negligible risk, by a digital exploration of the heart sac

Philadelphia has been interested in the surgery of the heart and pericardium for years. In 1876 an intern of the Pennsylvania Hospital made a search in its library for literature on pericardial tapping. Some results of this study were incorporated in journal articles<sup>1</sup> and later in Pepper's System of Medicine, 1885, in which an improved form of pericardial aspirating trocar was illustrated. This instrument has proved a useful device. It was described in 1877 and 1881. In October of the latter year, an article, read in Brooklyn, suggested the employment of pericardiotomy to permit the suturing of cardiac wounds<sup>2</sup>.

A suggestive article on cardiac suture by Block<sup>3</sup> appeared in 1882, which I mentioned before the College of Physicians of Philadelphia, in 1883. The present distinguished professor of therapeutics in Jefferson Medical College, Hobart A. Hare,<sup>4</sup> did experimental work in 1886 or 1887, on cardiac wounds, in which he showed that the fatality of these injuries was usually due to mechanical pressure within the pericardium produced by the bleeding.

The earliest American operation for suturing a cardiac wound was performed, if I am not mistaken, by the late Francis Stewart, a young surgeon, who died recently while holding the positions of surgeon to the Pennsylvania Hospital and professor of clinical surgery in the Jefferson Medical College.

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\* A recent study of pericardial surgery in the laboratory and wards of the Polyclinic Hospital.

<sup>1</sup> Read before the Fourth Annual Meeting of the American Association for Thoracic Surgery, Boston, June 6, 1921.

<sup>1</sup> Roberts, J. B. New York M. J. December, 1876, Paracentesis of the Pericardium, Philadelphia, J. B. Lippincott Company 1880, Tr. A. M. A., 1880.

<sup>2</sup> Roberts, J. B. Ann. Anat. & Surg., December, 1881, p. 250, Medical News Jan. 13, 1883.

<sup>3</sup> Block. Gaz. med. de Strasb., Oct. 18, 1882.

<sup>4</sup> Hare, H. A. Med. & Surg. Reporter 60 1886-1887.

Westbrook,<sup>5</sup> of Brooklyn, in 1882, advocated intentional aspiration of the heart auricle itself to relieve cardiac distention, in cases in which phlebotomy did not seem applicable. Corwin, Dana, Roberts and Leuf, in 1883, wrote on this operation of cardiocentesis, and Senn, in 1885, refers to it in the treatment of air embolism.

F. C. Shattuck and Charles B. Porter of Boston drew attention to clinical and experimental work in cardiac surgery in an important article read before the American Surgical Association in 1897. At that time I<sup>6</sup> advocated a thoracoplastic operation for reaching and dealing with the heart when wounded.

Pericardial tapping as a means of diagnosis was looked upon with increasing favor as these studies continued in various countries. The aid given by the aspirating vacuum attached to the hollow needle or trocar was recognized as increasing the efficiency of the diagnostic operation. The danger of unintentionally puncturing the heart wall and drawing blood from the right ventricle was recognized as being less liable to result in a fatality than missing the opportunity to save life through an early demonstration that the patient was dying slowly from pressure by accumulation of fluid within the pericardial sac. The needle with the internal sliding flexible evacuating cannula, already mentioned, greatly minimized the possibility of wounding the heart itself, even when fluid within the sac was small.

Another corroboration of the nonmortality of aseptic puncture of the normal ventricle, whether accidental or intentional, as shown by Hobart A. Hare and Westbrook, was its occasional occurrence without fatality when searching with the needle for fluid in cases diagnosed as pericarditis with effusion.

I have been surprised in one or two instances of this kind to see the external end of an ordinary aspirating needle pulsate with the heart beat, and blood flow from it without any disagreeable result to the patient except a moderate amount of pain. Striking the fluid through a needle puncture in another place has been followed by escape of the pericardial serum, and the patient has recovered without complication of any kind, notwithstanding the fact that the heart itself was tapped. It is possible, I admit, that the puncture, first made, might have traversed the dome of the diaphragm and drawn blood from the liver. It is needless to say that such a mishap as tapping the heart instead of the pericardial sac is a contingency to be avoided.

Puncture can readily be made under local anesthesia, or even without anesthesia, in rather stolid patients or in those who are partially dulled in sensitiveness or nervousness by imperfect respiration.

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<sup>5</sup> Westbrook. New York Med. Rec., Dec. 23, 1882.

<sup>6</sup> Roberts, J. B. Tr. Am. Surg. Assn., 1897, p. 101.

In March, 1904, I aspirated the pericardium in a man, 31 years old, in whom the diagnosis was somewhat indefinite, but pericardial aspiration was advised by the internist in whose care the patient was. The history will show the difficulty of arriving at an exact diagnosis of the intrapericardial condition by tapping. It is quoted here to justify the contention that pericardiotomy may be a better diagnostic operation than paracentesis.

Physical examination gave evidence of an enlarged area of precardial dulness and showed valvular murmurs. The apex beat was

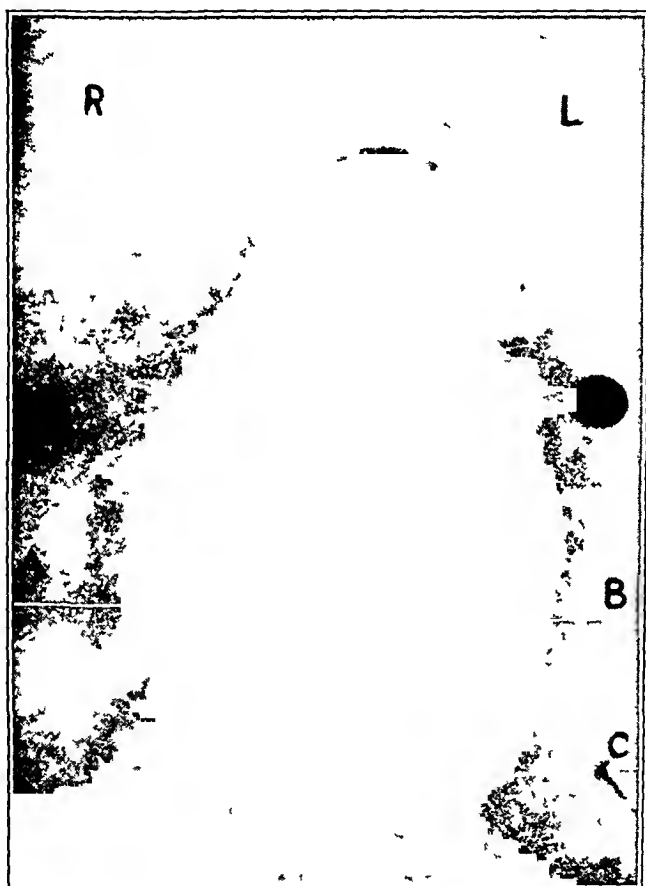


Fig 1—Roentgenogram of the pericardium of a cadaver, into which about 740 cc of plaster-of-Paris mixture had been injected. *A* indicates the point recommended for aspiration by Rotch, in the fifth interspace, from 4.5 to 5 cm to the right of the edge of the sternum, *B* indicates the point recommended by Roberts, in the fifth interspace, from 5 to 6 cm to the left of the median line of the sternum (probably the best point in most cases), *C* indicates the point recommended by Ferrand, at the fifth interspace, vertically below the nipple. The round buttons indicate the nipples.

seen and felt under the left nipple. The dulness extended to the right of the sternum. My belief was that the heart was hypertrophied and that there was not much pericardial fluid. Harsh breathing and some

dulness were recorded in the right chest, posteriorly. There was also heard what was either a pleuritic friction or fine bronchial râles at the base of the right chest, posteriorly. Dulness was also evident at the back of the left side of the chest. Weak pulse, rapid in rate, rapid breathing, dyspnea, and sweating were pronounced. It was not necessary for the man to sit up in order to breathe. My diagnosis was old valvular disease of the heart, with hypertrophy and pulmonary congestion or inflammation.

I, therefore, decided that tapping of the pericardium was not justified, because I was unable to convince myself that there was much fluid in the heart's sac.

The next day I was told that the man's condition was such that the attending physician, an expert internist, thought tapping was very desirable. He himself, unfortunately, could not be present to discuss the operative treatment with me. When I saw the patient, I found more dulness, apparently, than on my first examination. Otherwise I saw no especial change in physical signs.

I, however, accepted the point of view of the more experienced medical man than I, and decided to tap the pericardium with the internal flexible cannula and needle. I entered the chest in the fourth right interspace, close to the sternum, attaching the vacuum chamber after insertion of the needle into the tissues. Three fluidrams (11 cc) of slightly red fluid was obtained. The needle and cannula moved with respiration but not with the heart throb, proving that the protected needle point had not punctured the heart.

I then made a second puncture in the fifth left interspace, about  $1\frac{1}{2}$  inches (3.8 cm) below the nipple, to make certain that no large effusion had been missed. The end of the trocar seemed to strike the heart and perhaps to be embedded in the heart muscle, because it moved with such vigor with the heart beats. No fluid, except a few drops of blood, escaped. The pump brought very little fluid, and, after repeated attempts to get fluid, the instrument was withdrawn. Attempts had been made to get fluid by altering the position of the end of the cannula, but none was obtained. It did not feel as if the end of the trocar was free in a cavity of any size. The end of the cannula contained blood clot, and there was a free flow of blood from the wound until it was closed with cotton and collodion. The patient, at one time, complained of severe pain, and it was then that I thought the heart had been wounded.

The next day the patient seemed better, the pulse was stronger, and it was thought that the area of cardiac dulness on the right of the sternum was less. He died three days later.

Necropsy revealed no pleural effusion and no fluid, but a marked amount of lymph in the pericardium. The heart was greatly hyper-

trophied No mark was found of a wound of the heart, but this would probably have been concealed by lymph deposits

I had another experience, also with the flexible ended cannula needle, of a somewhat similar kind, in the case of a woman who had come to the Polyclinic Hospital with pericarditis and bronchopneumonia, under the care of Dr David Riesman

I aspirated in the fourth left interspace over the apex beat, which could be distinctly felt The point of puncture was about  $3\frac{1}{2}$  inches (89 cm) to the left of the middle line of the sternum, under the left mammary gland, and perhaps through its lower edge The Roberts pericardial trocar was employed, and worked satisfactorily, the vacuum of the aspirating pump being attached after a little fluid had flowed from the trocar The introduction of the needle, which was made without attaching the aspirator, was followed by pushing forward the internal cannula The trocar was introduced to a depth of about 35 cm The point gave the impression of being within a cavity, and the beat of the heart against it was easily felt The external portion of the trocar oscillated with the cardiac pulsations Three ounces (85 gm) of a very bloody serum was drawn off In order to make a strong

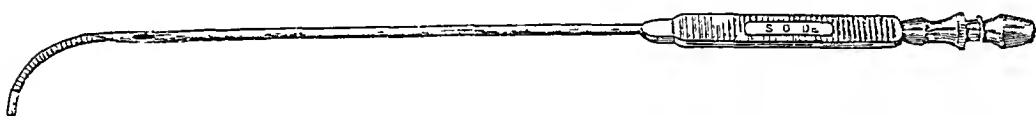


Fig 2—Roberts' pericardial aspirating trocar, consisting of a hollow needle and an internal cannula with a flexible end The cannula is pushed forward after the needle point enters the pericardium

vacuum, after the small bottle was about half filled, the aspirating apparatus was detached The contents of the bottle had coagulated so promptly that it took a little time to wash out the bottle and to obtain some of the fluid in sterile test tubes for bacteriologic examination The aspirator was attached to the trocar again, but no more fluid was obtained The wound was sealed with cotton and collodion

Percussion over the upper cardiac region after the patient had been tapped disclosed clearness where previously there had been dulness The woman, after the operation, seemed to breathe more easily, and had a better pulse Ethyl chlorid was used to freeze the skin before the puncture was made

Before the operation there was dulness of the right chest posteriorly, with moist râles There was marked dulness over the heart The dull area was somewhat irregularly triangular, with the base downward This dulness extended into the left axillary region The dull area seemed to be displaced forward when the patient turned on the right side The cardiac sounds and impulse were quite distinct in front,



and a friction sound was heard at the base of the heart. This was said to be less than on the previous day. The cardiac sounds were heard posteriorly. There were some râles, posteriorly, in the left side of the chest. The patient was breathing very rapidly and had a weak, rapid pulse, but she was able to lie flat on her back even before operation. The day after operation she was in better condition than on the day of operation, and the cardiac dulness, which had been diminished by operation, was not increased.

Three days later it was determined to make another aspiration because the pericardial sac had evidently refilled. A puncture was made with the Roberts trocar in the fifth interspace,  $2\frac{3}{4}$  inches (7 cm) to the left of the middle line of the sternum. The aspirating pump was attached, but nothing was obtained, except a very few drops of bloody fluid. The trocar was then withdrawn and found to be plugged. A second puncture was made in the same interspace,  $3\frac{3}{4}$  inches (9.5 cm) from the midline of the sternum. It obtained by aspiration  $4\frac{1}{2}$  fluid-ounces (133.4 cc) of dark, bloody fluid. The fluid was much darker and thicker than that obtained a few days before, and did not coagulate so quickly, if it coagulated at all. The trocar moved with the heart beats in both punctures, but not so vigorously as it did on the former occasion. At the last puncture the trocar was buried in the tissues for about 9 cm. The operator received the impression that the point was in a large cavity. At the first puncture the end seemed not to enter a large cavity, but to strike against some solid body within the chest. An increased resonance was obtained by percussion of the precordial region after the operation. The patient died early the next (?) morning.

Necropsy demonstrated the pericardial cavity nearly free from fluid. The heart was covered with shaggy lymph, particularly about its base, and there were adhesions between the heart and pericardium. The first puncture, made on the second day, scraped or went through the edge of the costal cartilage above the interspace.

Upon the front of the heart was a small ecchymosis, without apparent wound, that looked as if it might have been caused by contact with the end of the trocar. This fact could not be definitely confirmed, as the point of ecchymosis was not very marked. There was a considerable amount of fluid in the left pleural cavity, and pleuropneumonia was present. There was some congestion and consolidation of the right lung.

An incised wound of the fifth interspace of the left chest, made with a piece of glass with suicidal intent, which I saw on one occasion, has a bearing on the question in hand. The cut, which was approximately in the nipple line, laid open the pleural cavity and the pericardium. When the patient was brought to the Polyclinic Hospital

there was free bleeding. The intern cleansed the region and stopped the active bleeding. When I saw the man later, there was evidence of some blood in the pleural cavity, but he was in good general condition. I thought it unwise to undertake any active intervention, not knowing that the wound had split open the pericardium. The pleural wound was not large and had been packed with sterile gauze. I believed that if the hemothorax should become infected, I could easily drain and irrigate. The packing in the pleural opening was replaced after a day or so, and later a drainage tube, followed by irrigation of the cavity, was adopted as the line of treatment.

The patient did well for some days, but he died, some time after the injury, of pleuropneumonia. A thorough examination of the region then revealed the pleural opening and also disclosed a clean cut wound, of an inch (2.5 cm) or more, in the pericardium and a shallow incision in the wall of the heart near the apex, about 1 inch (2.5 cm) long. This wound was of no special significance in the case, but showed me how easily the heart can be reached for suture in deeper lesions of its muscle tissue.

It is probable that had I seen the patient immediately after the infliction of the wound, exploration with my finger would have revealed the pericardial and cardiac damage and would have led to a more radical line of treatment of the injury of the pleura. The young intern naturally, as perhaps I also might have done, gave more attention to arresting the evident bleeding, than of exploring the depths of the wound.

Thorough asepsis might have been followed by suture of both pericardium and pleura, perhaps with safety, and a small cigaret or rubber dam drain inserted superficially.

#### REPORT OF CASE OF RECOVERY AFTER DIAGNOSTIC PERICARDIOTOMY

*History*—The patient whose case prompted the preparation of this paper was a boy, aged 7½ years, who was admitted to the Polyclinic Hospital, July 24, 1919, and discharged, improved in health, Feb 11, 1920. He had been sent there by the pediatrician of the hospital with a diagnosis of pericarditis with effusion. A condensation of the hospital record is as follows: Tonsils, troublesome since 4 years of age, slight attack of influenza last September, varicella when 4 years old, family history, negative, appears that child had contracted amygdalitis from father and mother, three weeks previous to admission. He was taken to Dr. M., the pediatrician, because of pain in the stomach. Dr. M. sent the child to the hospital with a diagnosis of pericarditis with effusion. Examination of the eyes, ears and nose was negative. Both tonsils were enlarged and the lips were slightly cyanosed. Two teeth should have been removed, otherwise the teeth were in perfect condition. The posterior cervical lymph nodes were palpable, but the anterior nodes were not palpable. Both submaxillary glands were palpable. The lungs were negative. The heart showed an increased area of dullness, extending on the right side to the nipple line and beyond the nipple line on the left side. The heart sounds were fairly



Fig 3—Roentgenogram of patient, aged  $7\frac{1}{2}$  years, with hypertrophy of the heart, proved by pericardiotomy, which was supposed at the original examination to be pericardial effusion. The shadow of a safety pin is seen on the left side. It served to indicate the left side of the patient.

normal, but an evident to and fro murmur was transmitted to the left axilla mostly. The abdomen and extremities were negative.

The child was under treatment until September. September 9, a roentgenogram was made at the request of Dr M. The boy was sent to the laboratory with a clinical diagnosis of pericarditis with effusion and left pleural effusion. The roentgenologic report reads thus: "Pericardial effusion, there is a pronounced and overwhelming amount of fluid present and it is well defined by this examination, see no evidence of pleural effusion on either side. See plate" (Dr W.)

The temperature record for September varied from normal to 99 F, with occasional slight rises to about 100 F, until Sept 22, 1919. About this time it reached 101 F, irregularly, and oscillated between 100 and 101 F, dropping occasionally to about normal. Late in September, 1919, the temperature rose to 103 F, once or twice. During this month the blood pressure was diastolic, 70 and systolic, 94. The pulse from the time of admission was about 120, more or less. There was some increase in respiration after the first of August, but before that time it varied from about 20 to 30 per minute, and in September it increased to 50 and 60 per minute. About this time, the pulse rate was from 110 to 125 or 130 per minute, and the temperature varied between 99 and 101 F, rising later to 102 and 103 F.

Sept 30, 1919, Dr H. A. McKnight asked me to see the patient in consultation, as he had been asked to tap the pericardium, in his capacity as the surgeon on duty. The clinical diagnosis of pericardial effusion had been made by both the pediatrician and the roentgenologist.

Treatment had consisted of the application of ice to the precordia, and blisters had been caused by cantharidal plaster. Basham's mixture had been given internally, as well as calcium sulphid and acetylsalicylic acid, with orders for weekly urinalysis to be made, and frequent purgatives to be given. No frequent record had been made of accurate auscultation and percussion of the chest, although this examination may have been made by those in charge.

*Examination*—Our examination revealed rather loud cardiac sounds, with dulness in the precordial region, but the patient was not especially cyanotic and as he lay in bed his pulse was rather strong.

Dr McKnight and I discussed the fact that the clinical examination of the patient did not give the impression that he was suffering from a large pericardial effusion. He was not sitting up in bed panting for breath, and the cardiac impulse did not seem so feeble as it would have been with a large pericardial effusion. On account of the interpretative diagnosis of the roentgen-ray laboratory and the clinical diagnosis of the pediatrician, it was decided to make an exploratory puncture.

*Treatment*—An aspirating needle was inserted between the xiphoid cartilage and the seventh rib, but no fluid was obtained. Then an incision was made down through the left fifth interspace and pleura and pericardium were exposed. The needle was again inserted through the exposed pericardium, and no fluid except blood was obtained. The pericardium was opened by a small incision and the index finger inserted into the pericardial sac. No fluid was obtained, but a very large heart was found.

Considerable trouble was experienced as a result of bleeding from the internal mammary artery, which made the operation more tedious. This was stopped by a hemostatic clamp, which was left on when the wound was sutured. The pleura was torn probably by a finger, in exploring the cavity of the

pericardium. A piece of sterile gauze was pushed in through the wound in the pleura, and the patient was returned to bed in fair condition. The anesthetist, Miss Bonner, recorded that the patient was a poor subject for ether, his pulse being so rapid at the beginning that it was impossible to count its rate.

Dr H. A. McKnight performed the operation, Dr Hawthorne and I assisted. The amount of ether used was  $2\frac{1}{2}$  ounces (74 cc).

*Course.*—Digitalis was given after operation, with strychnin sulphate,  $\frac{1}{150}$  gram (0.00043 gm.), every three hours, by hypodermic injection. Camphorated oil was also given hypodermically. This general stimulating treatment, with camphorated tincture of opium (paregoric), was continued and later changed to Basham's mixture. Sodium bicarbonate and phenyl salicylate were given before meals. The patient, in a short time, reacted and continued to improve above the condition that existed before operation. This improvement was evidently due to change in treatment resulting from the correction in diagnosis, and, perhaps, to relief of pressure on the enlarged heart by the incision in the heart sac, which must have enclosed the large heart tightly, previous to the operation. A revised diagnosis of chronic valvular disease of the heart, mitral regurgitation with decompensation was made. This was evidently the cause of the hypertrophy found at the time of the pericardial operation. Inquiry made at the child's home, many months later, revealed the fact that no apparent disability had resulted from the pericardiotomy performed in 1919 or a later amygdalectomy.

Urimysis, which was recorded, Dec 8 1919, revealed straw colored urine with a specific gravity of 1.015, acid, no albumin, no casts, no leukocytes and no pus. There was no amorphous sediment, but a few crystals of urates.

The urine when the child was admitted was deep yellow, with a specific gravity of 1.029, acid, slight flocculent sediment, no albumin or sugar. Occasional hyaline casts were observed, as well as epithelial cells and leukocytes, no pus, a few bacteria and some mucus.

The leukocyte count on admission was 9,920, polymorphonuclears, 53 per cent, transitionals, 32 per cent, lymphocytes, 15 per cent, large mononuclears, 13 per cent, eosinophils, 15 per cent, hemoglobin, 76 per cent, red cells, 4,330,000. About the time of the operation the leukocytes increased in number to 18,400, hemoglobin was 71 per cent, red cells, 4,600,000. The urine continued to be negative as to albumin and sugar during this entire period.

Valuable additional history was obtained after the operation. The child had been taken acutely ill, June 23, 1919, with high fever, general depression and malaise. He was in bed one week, then he got up and felt better. In July he had an attack of pain in the upper abdomen, diagnosed as gastro-intestinal colic. His breathing had been distressed and rapid. The child never complained of dyspnea and cardiac pain until very recently. He had always had bad tonsils and he had had three severe attacks of tonsillitis. There had been no history of rheumatism, but slight sore throat during the influenza epidemic. The general health greatly improved from week to week.

More than two months later, the patient was etherized with nitrous oxide and ether and operated on for hypertrophied tonsils and adenoids. Miss Bonner reported that the pulse was rapid but fair and that the child took the anesthetic well. The operation was performed in Dr Ralph Butler's department.

#### COMMENT

This and other experiences in pericardial surgery have seemed to offer strong evidence in support of the opinion that careful investiga-

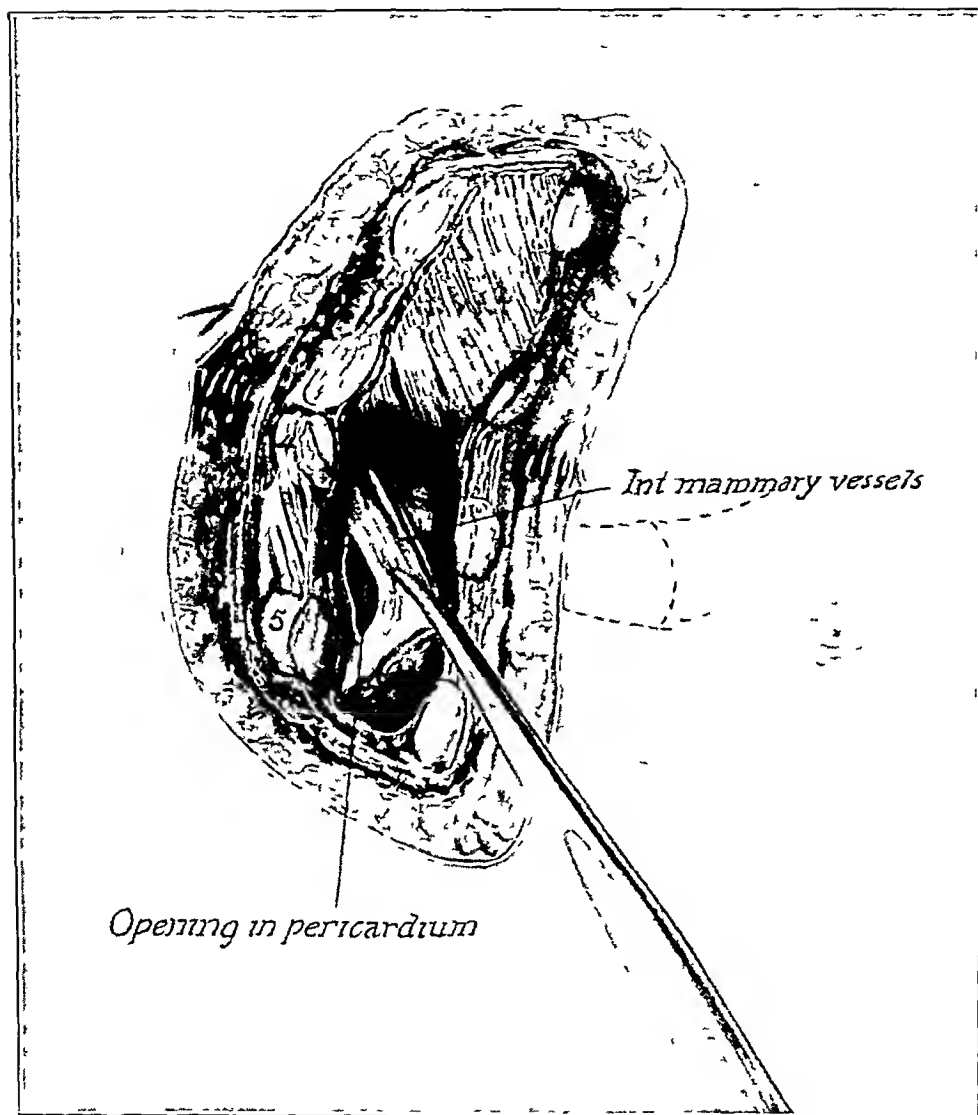


Fig 4—Author's chondroplastic method of pericardiotomy by a trap-door excision of the costal cartilages, which prevents injury to the pleura and internal mammary vessels. The flap, consisting of portions of the fourth and fifth cartilages and the attached soft parts, is turned upward, exposing the left lung covered with pleura and the internal mammary vessels. The forceps are holding the vessels and the edge of the pleural sac outward, so as to expose the white pericardium, in which an opening, indicated in black, has been made.

tion should always be made by percussion, auscultation and roentgenographic study before resort is had to tapping, or other surgical attacks, as the line of treatment in suspected pathologic conditions of the heart. They, however, show also the difficulty that may arise in differentiating with accuracy the cause of the objective and subjective symptoms presented to the clinician for diagnostic interpretation.

Recent researches and numerous war experiences in treatment of thoracic wounds and the acknowledged innocuousness of pericardial incisions indicate that it may be at times not only wise, but imperative, deliberately to open the sac of the heart for diagnosis. It will be admitted that this somewhat radical procedure should be adopted in only a comparatively few instances and by surgeons familiar with the surgical anatomy of the precardial thoracic wall.

The differential diagnosis between pericardial effusion, pericardial empyema, intrapericardial bleeding, hypertrophy of the heart, dilatation of the heart, rupture or wound of the heart wall and foreign bodies within the heart sac or embedded in the heart itself may be obscure. The outlook for the patient may become very gloomy. The surgeon under such circumstances, especially when there are various combinations of these pathologic possibilities, is driven to exploration of the interior of the pericardium.

The situation of the patient and the responsibility of the surgeon are then similar to those existing in obscure lesions of the abdominal, pelvic, cranial and pleural cavities. Investigation must be made by endoscopic, visual, and digital exploration of the pericardial sac and perhaps even of the heart wall and its cavities.

Laboratory researches have apparently proved the possibility of entering even the hollow heart and remedying defects of its valvular apparatus. It is not difficult to believe that small growths within the heart, of syphilitic or other origin, might be excised and small aneurysms of the coronary arteries be surgically obliterated. A rapid and skilful operator might possibly have time to do intracardiac work of value to a suffering patient while the blood current was controlled by twisting or compressing the vessels carrying the inflow of blood.

Operations for withdrawing embolic air from within the heart by aspiration, Tiendelenburg's operative removal of blood clot from the pulmonary artery, by means of a pericardial entrance through the second intercostal space, procedures for relieving cardiac adhesions and lessening impeding pressure on the organ's mobility are instances of what have become advances in cardiac surgery.

Hare insisted years ago that the reduction of mortality from cardiac wounds was in its essence simply a mechanical problem, and that it was intrapericardial pressure which the surgeon should seek to remove and then deal with the damage in the muscle of the heart.



Fig 5—Goodman's incision of thoracic wall for exposure of the pericardium (Courtesy of Dr Charles Goodman)



In the case reported in this paper it is possible that the incision in the pericardium encasing the greatly enlarged heart was an important factor in the child's subsequent return to health.

Aspiration of the right auricle and puncture of the right ventricle probably are, as Ballance says, no more valuable and much more dangerous than operative bleeding from the external jugular vein to relieve an overstretched heart. Intentional puncture of the left side of the heart may doubtless be employed with less likelihood of dangerous effects than similar operations on the right side of the sternum to deplete the right side of the heart.

Pericardiotomy is not an operation requiring an unusual amount of surgical skill. It should be performed on the left side of the breast bone, as a routine, in order to reach fluid for the purpose of clearing up a diagnosis or of instituting treatment. I cannot quite agree with Ballance's statement in his recent very valuable Bradshaw lecture that "aspiration of the pericardium should be banished as a surgical practice." Aspiration with a properly selected instrument, such as the dome-shaped trocar of Stewart (?) of Halifax or the pericardial instrument depicted in this paper makes accidental puncture of the left side of the heart very improbable.

A large hypodermic needle, like that of the veterinarian's syringe, will probably always be obtainable and may be used to establish the presence or absence of fluid in the heart sac when pericardiotomy is being considered.

The inner extremity of the space between the sixth and seventh ribs is sometimes absent, because of the contact of the costal cartilages of these ribs, just before they join the sternum. This approximation may be such that it leaves a small slit through which a needle for aspiration may be passed, if it were possible to recognize its exact position, through the overlying soft parts. This difficulty makes aspiration occasionally ineffective because the needle becomes plugged with a piece of cartilage during its passage through the wall.

This difficulty makes pericardiotomy close to the sternum in the sixth interspace often impossible without excision of the sternal ends of the sixth and seventh cartilages. The exact shape of the costal cartilages in this region might be determined and marked on the surface by roentgenographic study prior to aspiration.

Pericardiotomy in this region, as performed by Pool, and permanent drainage for suppurative pericarditis include resection of about an inch of these two cartilages. His method is an excellent one if the surgeon believes it impossible to establish permanent drainage through an opening in a higher part of the pericardial sac. I am rather inclined to believe that pericardial suppuration may be successfully treated by

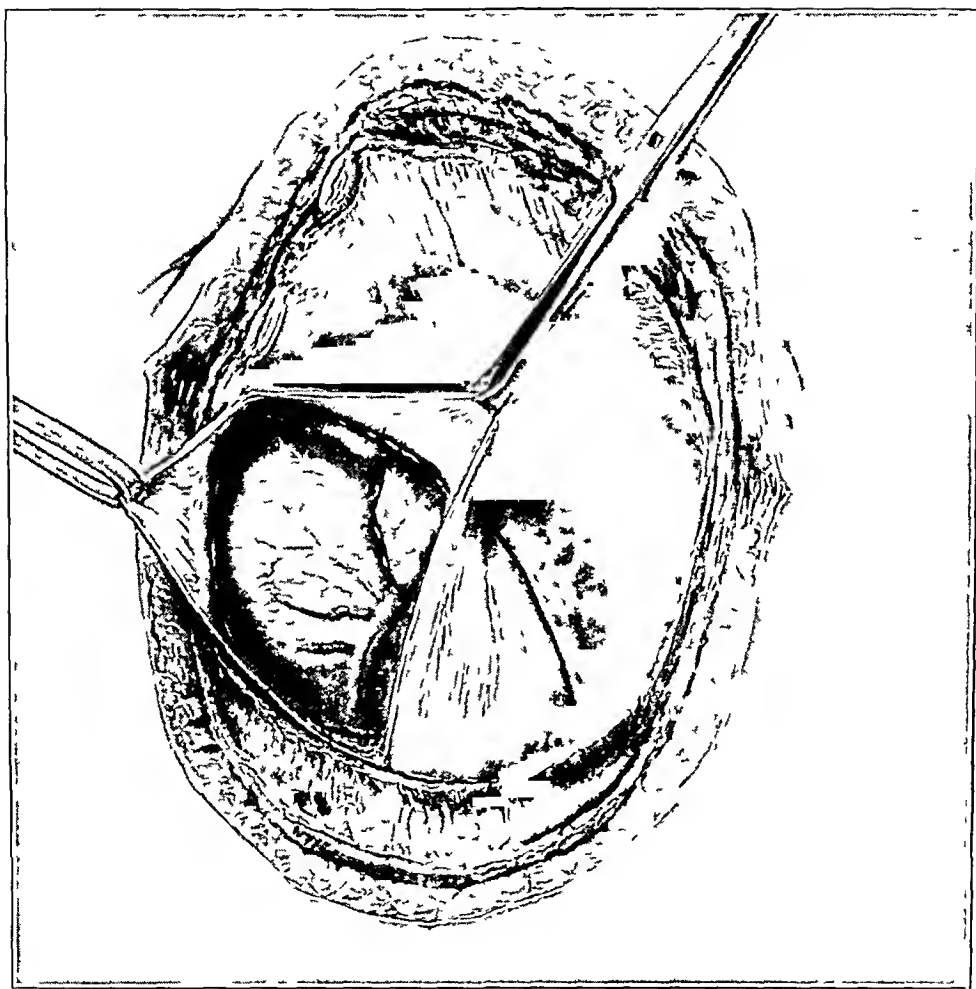


Fig 6 — Goodman's triangular flap of thoracic wall raised. The pericardium incised longitudinally affording free access to the heart. The parietal pleura, separated by blunt dissection from the anterior wall, remains unopened (Courtesy of Dr Charles Goodman)

means of an opening made in a higher interspace, where there is more distance between the two cartilages. It is my belief that pericardial pus may be evacuated and the cavity drained and sterilized by frequent irrigation with phenol solution or surgical solution of chlorinated soda as may be done in pleural suppuration. It will require that the patient with pericarditis should lie in the prone position and have frequent washing out of the cavity. I seldom, if ever, resect the ribs in pleuritic empyema and I should, therefore, be inclined to do without it in suppurative pericarditis.

Dr. Pool, however, has had experience with his operation by which he excises subperiosteally the ends of the sixth and seventh cartilages and shows excellent results.

Dissections of this region have shown me marked deviation in the relations of the sternal ends of the costal cartilages to one another. The shape of the xiphoid appendix of the breast bone also varies. Operators should make themselves familiar with these aberrations in shape and the intercostal bridges, especially in preparing for aspiration or incision of the pericardium. The forked shape of the xiphoid and its usual attachment near the posterior surface of the gladiolus should be recollected. The occasional foramen in the gladiolus may surprise one.

Diagnostic pericardiotomy should, in my opinion, be employed in the interval between the fourth and fifth ribs or between the fifth and sixth ribs, where there is sufficient space to admit the surgeon's index finger up to the very base. In the fourth space the middle of this incision should be just at a point a little to the right of and below, the nipple, close to, but below, the upper edge of the fifth rib. If the fifth interspace is chosen, the wide part between the fifth and sixth ribs is a little farther toward the axilla than in the fourth interspace, the incision should be about 6 cm. long and begin, if the fourth interspace is taken, about 1 cm. from the edge of the sternum. An elliptical flap, with the convexity downward, should be turned so as to expose the entire width of the fourth interspace.

It will be necessary usually to tie the internal mammary artery with two ligatures, the artery then being divided between them. The pleura may sometimes be pushed to the patient's left. If, however, it is opened with the knife or by blunt dissection, no great harm is done. After opening the pericardium and exploring its interior and the heart with the finger, the pleural rent may be closed with a suture or by means of packing. Neither wound of the internal artery nor opening the left pleural cavity will seem to be serious complications to an experienced surgeon. If a large pneumothorax is produced by the mishap of opening the pleura, air may be withdrawn after the wound is closed by

aspiration in the axillary line. Infection of the pleura may occur, however, if pus escapes into it from the opened pericardium. This is more serious.

If the pericardium is believed to contain pus, a small puncture with the veterinary hypodermic syringe may be made before opening the pericardium. If pus is found by this means, a new incision may be made nearer the sternum or drainage may be provided in that region and thus the pleural cavity saved from possible contamination.

Whenever it is necessary to expose the heart for wound caused by a foreign body, a somewhat triangular osteoplastic flap should be turned up by dividing the fourth and fifth cartilages, as suggested by me in 1897, using the intercostal muscles as a hinge, or by the trap door suggested by Delorme, about the same date. Delorme makes the hinge at the edge toward the axilla. Goodman's incision for a flap is lower than that suggested by me, but, I understand, that the intercostal muscle also is used as the hinge for raising the trap door.

[AUTHOR'S NOTE—Since Lauder Brunton in 1902 (*Lancet* **1** 352) raised the question of surgical attack on stenotic mitral valves, considerable attention has been given to that topic. Drs. Duff S. Allen and Evarts A. Graham published, three months ago (*J. A. M. A.* **79** 1028 [Sept. 23] 1922) a very valuable study of endocardial operations on this valve by means of an electro-scope and a sheathed knife introduced into the cavity of the heart of dogs. Several animals were living several months after such experimental endocardial operations, performed with precision because valve leaflets are cut within the operator's field of vision.]

# CHRONIC NONINFLAMMATORY LESIONS OF THE KNEE JOINT \*

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The knee joint is the largest joint in the body, and one looks at its structure in the skeleton, only to marvel at its stability during life. The two broad surfaces of the femur and tibia are fitted together only lightly, the round condyles of the femur resting in the slightly concave surfaces of the tuberosities of the tibia. The semilunar cartilages deepen somewhat the shallow fossae for the reception of the condyles, and to a certain extent increase stability, although they do not act as ligaments. They are fibrocartilaginous and, therefore, are more prone to rip or to tear than they are to fracture. The patella is a sesamoid bone, and is of importance in maintaining stability of the joint only so far as its association with the quadriceps muscle is concerned. It is, therefore, evident that the strength of the knee joint must be furnished by a satisfactory system of ligaments, and by such support as may be obtained through the action of the muscles.

For the consideration of the surgeon, the knee joint may be divided into an anterior superior compartment (the suprapatellar pouch), and an anterior inferior compartment (Fig 1), which may be subdivided into internal and external sections containing the internal and external semilunar cartilage, and a posterior compartment, also subdivided into internal and external sections (Fig 2). The anteroposterior middle line, in which lie the tibial spine and the crucial ligaments, divides the anterior compartment into two sections, inner and outer. The anterior boundary of these sections is the anterior capsule of the joint, while the posterior boundary may be said to be the posterior margins of the semilunar cartilages (Fig 2). The posterior compartment is the space bounded behind by the posterior capsule from its line of reflection on the condyles of the femur and the tuberosities of the tibia, and by the bones in front. It is practically obliterated in complete extension, but is larger when the knee is flexed to a right angle. There is usually a mesial septum fastened in the intercondylar notch that divides this posterior compartment into internal and external sections. It is of importance when osteocartilaginous bodies in this situation are to be removed (Fig 2). Were it not for this septum, one could readily remove a loose body from the posterior external section through an

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\* From the Section on Orthopedic Surgery, Mayo Clinic

\* Read before the Idaho State Medical Association, Wallace July, 1922

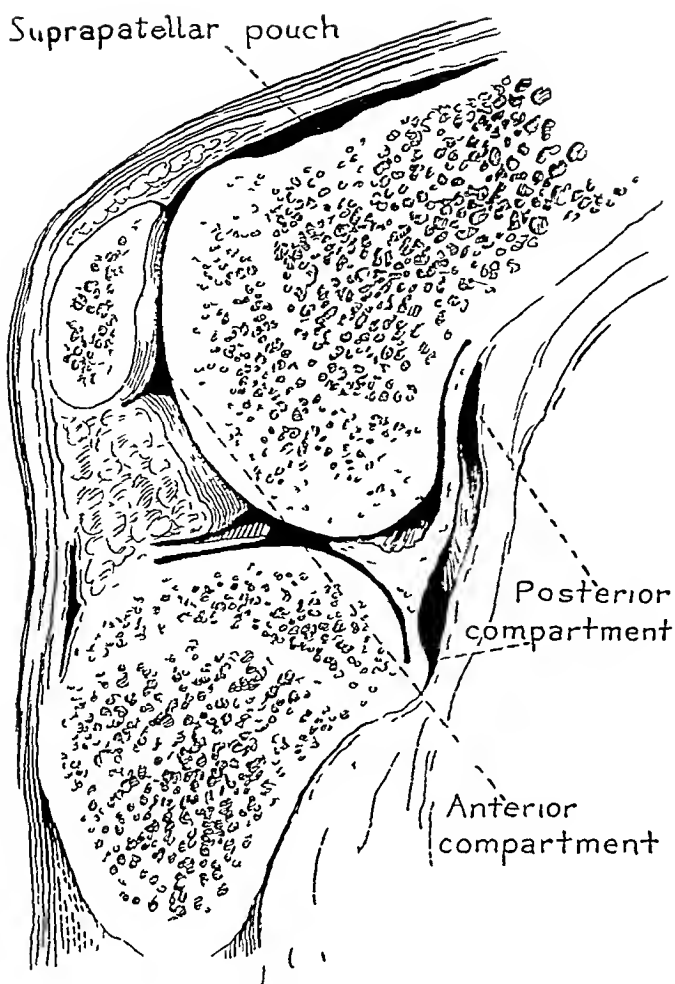


Fig 1—Sagittal section through the external condyle of the left femur, for convenience the joint is divided into compartments

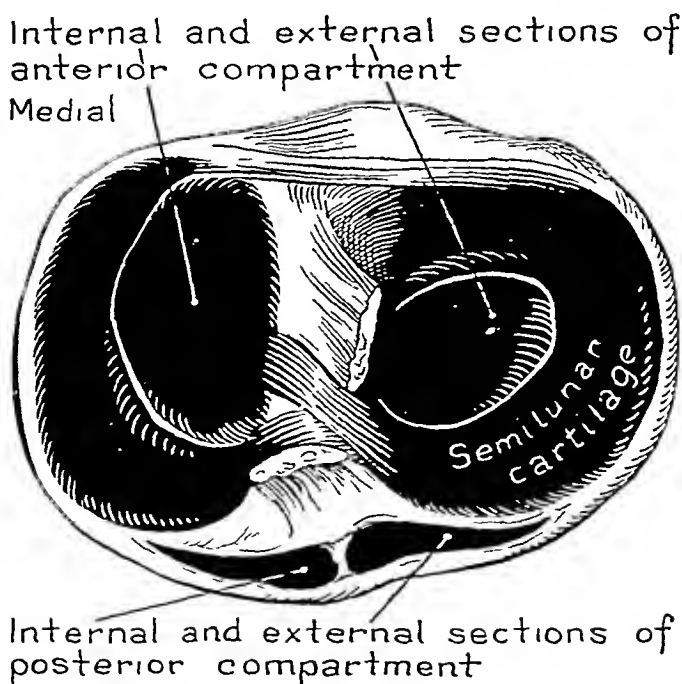


Fig 2—Head of the tibia with semilunar cartilages, position of the anterior and posterior compartments

internal posterior incision or vice versa, but usually incisions must be made on both sides if bodies are multiple and are in each posterior section

The capsule of the knee joint, by a special system of reinforcements, furnishes the ligaments. The external lateral ligament is entirely

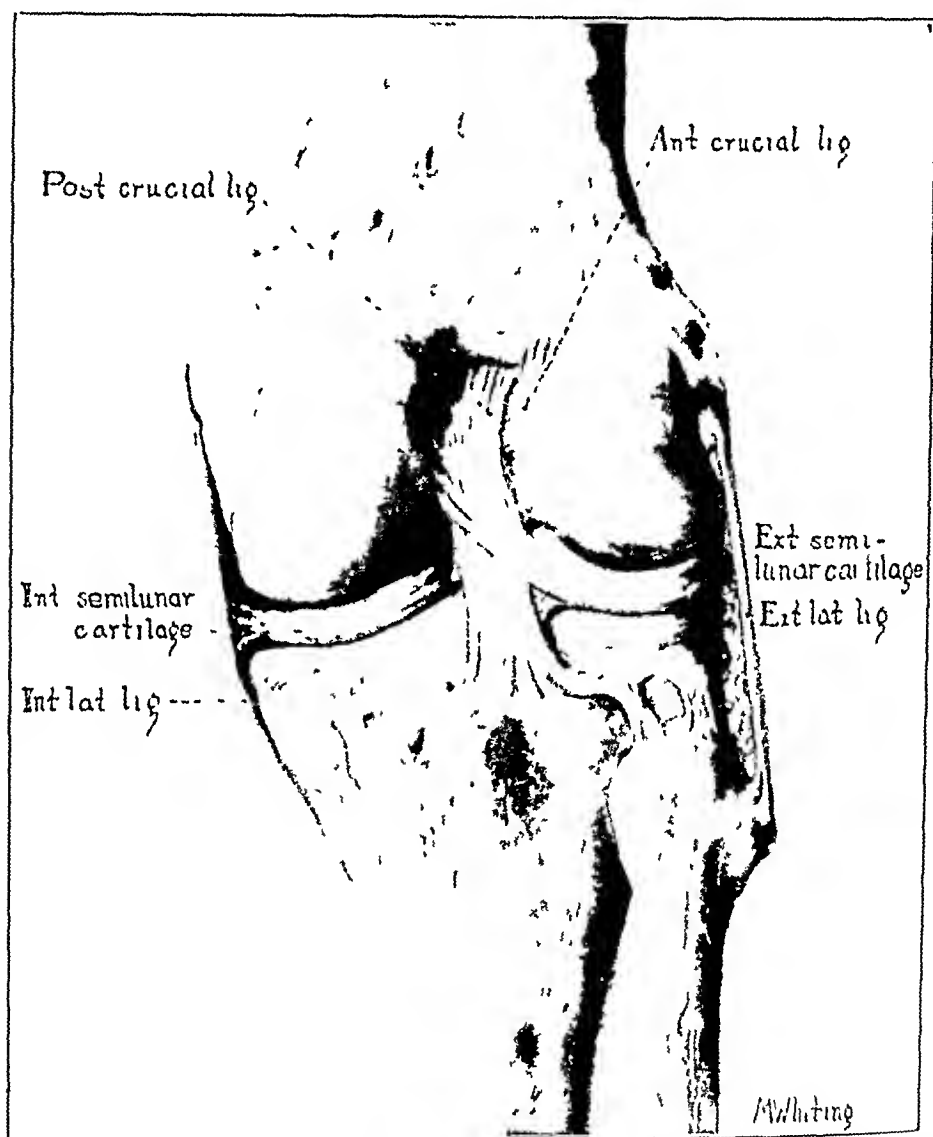


Fig 3—Intimate relation of internal semilunar cartilage to internal lateral ligament and the lack of this relation of the external semilunar cartilage to the external lateral ligament

separate from the external capsule and forms the only really definite ligament in this group of outer ligaments (Fig 3). The posterior capsule of the knee joint is a weak posterior ligament, and is of but little aid in preventing hyperextension of the knee joint. The internal lateral ligament is most interesting on account of its intimate associa-

tion with, and firm attachment to, the periphery of the internal semilunar cartilage (Fig 3) It is difficult to define the exact extent of this ligament, as it extends along the entire inner side of the joint The internal semilunar cartilage, situated in the anterior internal section, is C-shaped, a little more than a half moon A few fibers of the vastus



Fig 4—Posterior cruciate ligament in relation to the condyle of the femur

internus are prolonged down onto, and are attached to, the internal capsule and, therefore, to the internal lateral ligament This is of importance because in certain positions of the knee joint, and under certain actions of the quadriceps muscle, these fibers may contract and definitely disturb the normal anatomic relationships of the internal



capsule, the internal lateral ligament, and consequently the internal semilunar cartilage. Therefore, so far as concerns this study, the points of the anatomy of the inner side of the knee joint of particular importance are (1) The internal lateral ligament is not a definitely developed structure, in reality it is the internal capsule. (2) The internal semilunar cartilage is firmly attached at its periphery to the internal capsule. (3) The vastus internus fibers are inserted low enough on the internal capsule to cause, in certain positions of the knee joint and under certain conditions of muscular contraction, a distortion of the internal capsule and the semilunar cartilage attached to it.

The anterior external section of the knee joint is the portion between the external condyle and the outer tuberosity of the tibia, and contains the external semilunar cartilage. This meniscus is more nearly circular than the internal, is wider, and, again unlike the internal, is quite loosely attached to the external capsule of the joint (Fig. 3). It should, moreover, be remembered that there are no muscular fibers inserted into the external capsule, and, therefore, the relation of the external capsule to the external cartilage cannot be interfered with by any action of the muscles.

The crucial ligaments, situated in the middle of the joint are of great aid in furnishing stability to the knee joint. The posterior crucial ligament runs from the spine of the tibia upward, forward and inward, to be inserted anteriorly in the external surface of the internal condyle of the femur in the intercondylar notch, thus preventing the tibia from slipping backward on the femur. It also has some effect in limiting extreme flexion, but the impaction of the calf against the thigh is, in reality, the main check to excessive flexion. Therefore, it may be assumed that the chief function of the posterior crucial ligament is to stop the tibia from slipping backward on the femur, or vice versa (Fig. 4).

The anterior crucial ligament runs from the tibial spine backward, upward and outward, to be inserted posteriorly on the internal surface of the external condyle of the femur in the intercondylar notch. This ligament prevents hyperextension of the knee and slipping forward of the tibia on the femur, or vice versa.

The patella is occasionally guilty of both habitual outward dislocation and fracture. Displacement inward is extremely rare, first, because the inner condyle of the femur is high, which prevents it from sliding inward, and, second, because the external capsule, as it runs up to the patella, is shorter and stronger and has not the degree of elasticity of the internal capsule. Genu varum or knock-knee is more common than the genu valgum or bow-leg, particularly in women. Even a slight degree of knock-knee tends to throw the patella outward. This can easily be demonstrated on any patient with knock-knee. If a plumb

line is dropped down the middle of the thigh to the ground while the patient is standing erect, the part of the patella to the outside of the line will exceed that portion to the inside

The knee joint is superficially placed, and effusions are easily detected. The suprapatellar pouch is connected with the main part of the knee joint, and acts as a safety reservoir for chronic effusions. Not infrequently the suprapatellar pouch of the knee joint is distended so that it extends 10 or 12 cm above the patella.

The only nerves and vessels of importance about the knee joint are located posteriorly in the popliteal space, and at the head of the fibula where the external popliteal nerve winds its way around to the front of the leg. During operations, care must be taken not to cut the internal capsule too freely, or it may be weakened and fail to serve as an efficient internal lateral ligament.

The knee joint is essentially a hinge, and the motions permitted are flexion and extension. Slight lateral and rotary motions are permitted, however, in certain positions, which is of extreme importance in the production of certain pathologic conditions. Accepting Clark's<sup>1</sup> classification as a basis for recording joint motion, 180 degrees are attained with the knee in full extension. The angle at which the lateral and rotary motions are permitted is between 150 and 170 degrees, and may be spoken of as the "arc of weakness" of the knee joint. The last motion in full extension of the knee is slightly rotary. This is due to the fact that, when the knee is extended and the person is standing, the line of weight-bearing runs through the external condyle of the femur and the external tuberosity of the tibia. As the movement of extension is completed, the internal condyle rolls slightly forward and outward on the internal tuberosity of the tibia.

Hyperextension of the knee joint is limited chiefly by the anterior crucial ligament, but this fact is of little practical importance in this study. The posterior crucial ligament, however, limits the sliding backward of the tibia on the femur, and is of importance since many times persons walking or running meet obstructions, such as a bump on the shin, which block the forward motion of the leg. The body above the knee then tends to go forward and is stopped chiefly by the action of the posterior crucial ligament (an important point in considering the etiology of loose bodies in osteochondritis dissecans) until full extension is reached, when the anterior crucial ligament, the posterior capsule, and the hamstrings are called into play. The foregoing brief review of the anatomy and physiology of the knee joint forms a foundation for the points under discussion. (1) sprains, (2) rupture

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<sup>1</sup> Clark W. A. A Protractor for Measuring Rotation of Joints. *J. Orthop. Surg.* **3** 154-155 (April) 1921.

of the crucial ligaments, (3) intra-articular fracture of the knee joint, (4) recurring dislocation of the patella, (5) old ununited fracture of the patella, and (6) intrinsic mechanical derangement, due to the semilunar cartilages and loose bodies

#### SPRAIN

This condition of the knee joint is not uncommon, particularly in persons participating in active sports, such as football, baseball, tennis and hurdling. The internal lateral ligament is involved in most instances. The differentiation of damaged internal semilunar cartilage and sprain of this ligament is not always easy, but there is no locking with a sprain, and, as a rule, a full range of passive motion is permitted. Effusion may follow either condition, but it more often follows injury to the cartilage. Rest in the extended position for a few days, followed by baking and massage, usually relieves the patient. When pain and tenderness persist, raising the inner side of the sole and heel often affords great relief by removing the strain from the internal lateral ligament.

#### RUPTURES OF THE CRUCIAL LIGAMENTS

From time to time, articles have appeared in the literature, particularly in the English literature, on the restoration of ruptured crucial ligaments. The objective symptoms are apparently quite definite. If the anterior crucial ligament is torn, hyperextension of the knee is permitted and the femur slides backward on the tibia, or the tibia may slide forward on the femur. When the posterior crucial ligament is torn, the femur may be pushed forward on the tibia, or the tibia backward on the femur. Rupture of these ligaments occurs rarely. I have yet to see a patient with a long-standing disability that could be traced definitely to ruptured crucial ligaments. Therefore, it would appear that the condition is infrequent, and, at least, that the danger resulting from ruptured crucial ligaments has probably been overestimated. I have treated a few patients who had clearly demonstrable ruptured crucial ligaments at the time of the original injury, but by merely placing the patient's leg in a plaster-of-Paris cast, in a slightly flexed position, excellent function has been obtained.

#### THE INTRA-ARTICULAR FRACTURES OF THE KNEE JOINT

Severe direct trauma to the knee joint may produce fracture of either the internal or external tuberosity of the tibia or of the condyles of the femur. I speak of this condition because patients are often seen who, following such an injury, complain of arthritis, with pain on motion. Very little can be done for such patients, short of an arthrodesis, which most of them, quite properly, will not permit. In

a consideration of the effect, the cause also must be considered, and the question comes up as to whether much can be done when the fracture is first sustained. As a rule, these fractures are the result of severe trauma, the spongy bone is crushed, and, unless the displacement is marked and accompanied by little destruction of bone substance, it is very doubtful whether even an open operation would secure any better replacement of the fragments. Such cases are troublesome to handle, and, as I have said, in this particular type of injury, prolonged fixation in a cast or splint is prone to leave a stiff joint. Early motion is essential, and if it can be carried out under extension, the pain is less severe. The use of a modified Thomas splint with a joint at the knee is convenient. The regular measures of physiotherapy should be persisted in until soreness leaves the joint. After that, free, active use is the best. Many patients are left with more or less permanent disability.

#### RECURRING DISLOCATIONS OF THE PATELLA

The patella always dislocates outward. Patients may insist that the dislocation is inward, believing that the prominent internal condyle of the femur which is so noticeable during the dislocation, is the patella. Many operations have been devised for this condition, and all have been more or less satisfactory. The method I have found quite satisfactory is relatively simple, that is, merely reefing the inner capsule, and overlapping it broadly after lengthening the outer capsule. It is not necessary to open the cavity of the knee joint, although there is no serious objection to doing so. Dislocations of the patella are more commonly seen in women, in many instances, there is undoubtedly a familial tendency. Albee<sup>2</sup> advocates raising the outer condyle of the femur by placing a wedge-shaped piece of bone in it. He contends that the dislocations are the result of malformation due to imperfect development of the external condyle, and there seems to be a foundation for this argument.

#### OLD UNUNITED FRACTURES OF THE PATELLA

Such fractures, with wide separation of the fragments, are difficult to treat. The disability may be great, on the other hand, certain patients accommodate themselves remarkably well to the condition. The object of the treatment is to obtain bony union. A common fracture is one in which the lower fragment is small and the upper fragment is large, the distance between the fragments being 6 or 7 cm. It seems almost impossible to bring these fragments together as the quadriceps will not stretch enough to permit it and there is absolutely

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<sup>2</sup> Albee, F. H. *Orthopedic and Reconstruction Surgery*, Philadelphia: W. B. Saunders Company, 1919, p. 627.

no stretch in the patellar ligament. I make a long straight incision in the middle line, expose the fragments regardless of the degree of exposure of the joint, and freshen the ends of the fragments until good bone is reached. Not infrequently, the lower fragment will be tilted so that the fractured surface faces forward. In attempting to bring the fragments together, little can be gained by lengthening the patellar tendon. Therefore the upper fragment must be brought down

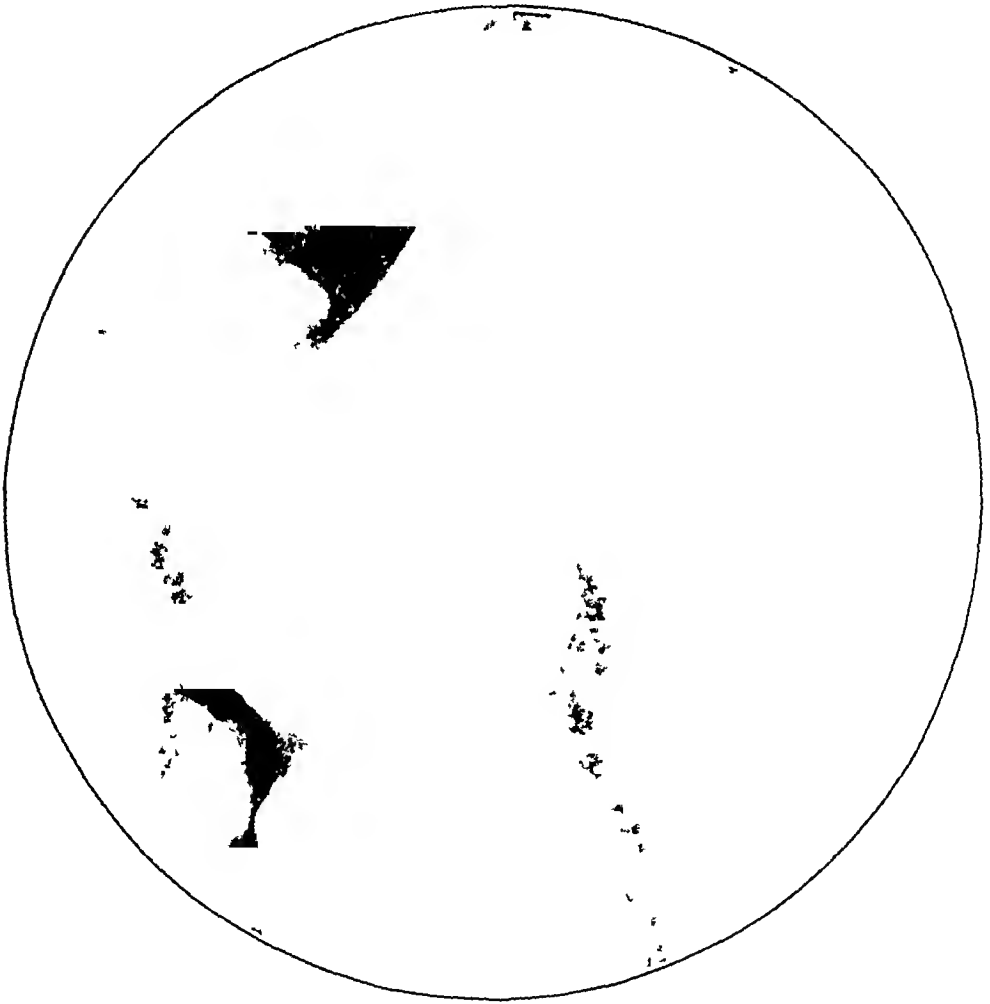


Fig 5—Ununited fracture of the patella of two years' duration

to the lower, even if it is necessary to dissect the upper entirely free from its attachments, making a veritable bone graft. The gap left by the patella, where it is removed from the quadriceps, is obliterated by sewing the muscle and fascia together, tissue is sewed around the patella in its new position, and the coapted fragments are held in place by the aid of beef bone screws (Fig 5). The main point to be remembered is that the fragments must be brought together without

tension, no matter what material is used to hold them, beef bone screws (Fig 6), kangaroo tendon, or wire. In the after-care, slight passive motion is commenced in about four weeks, and, soon after, slight active motion is encouraged. It is true that it takes time, probably six months or a year, for flexion to a right angle to be obtained, but satisfactory motion almost invariably returns.

#### INTRINSIC MECHANICAL DERANGEMENTS OF THE KNEE JOINT

The semilunar cartilages are the most common cause of mechanical derangement, and the internal semilunar cartilage is by all means the most common source.

A great variety of tears in the internal semilunar cartilage has been described and much has been written on this subject by English authorities.<sup>3</sup> Morison<sup>4</sup> has described in detail the various types of fracture commonly met. One type in particular, the bucket handle, named because of its resemblance to the old fashioned leather handled bucket little known in America, seems to be the most common. Perhaps the more appropriate term for such a fracture or tear would be the loop type of tear. The cartilage, which is torn longitudinally near its attachment to the internal capsule in the middle three-fifths is left attached at the anterior and posterior one-fifth, and the loop thus formed lies in the intercondylar notch (Fig 7). This position of the loop prevents full extension of the knee and causes locking. The internal semilunar cartilage is the cause of mechanical derangement probably from twenty to thirty times more often than the external. Sir Robert Jones<sup>5</sup> has said that a damaged internal semilunar cartilage may cause symptoms on the outer side of the joint. If the external cartilage is at fault, it is more likely to be detached at its periphery and crumpled, although it may also be torn.

When the knee is flexed at an angle of about 160 degrees and the foot everted, throwing the body weight on the leg causes a strain on the internal lateral ligament. In this particular position, slight lateral mobility is permitted, and the semilunar cartilage is placed deeper in the joint than in any other position, thus rendering it more liable to be caught by the internal condyle of the femur as it rolls down during the act of extension. The final part of extension has in it a slight

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3 Jones, Robert. Notes on Derangements of the Knee, Based upon a Personal Experience of Over Five Hundred Operations. *Ann Surg* 1 959-1001, 1909, Internal Derangements of the Knee, *Lancet* 2 297-300, 1914. Martin, quoted by Morison, R. Injury to the Semilunar Cartilages of the Knee. *Lancet* 1 604-607, 1909, Injuries to the Semilunar Cartilages of the Knee-Joint. *Chir J* 42 1-7, 1913.

4 Morison, R. References given in Footnote 3.

5 Jones, Robert. References given in Footnote 3.

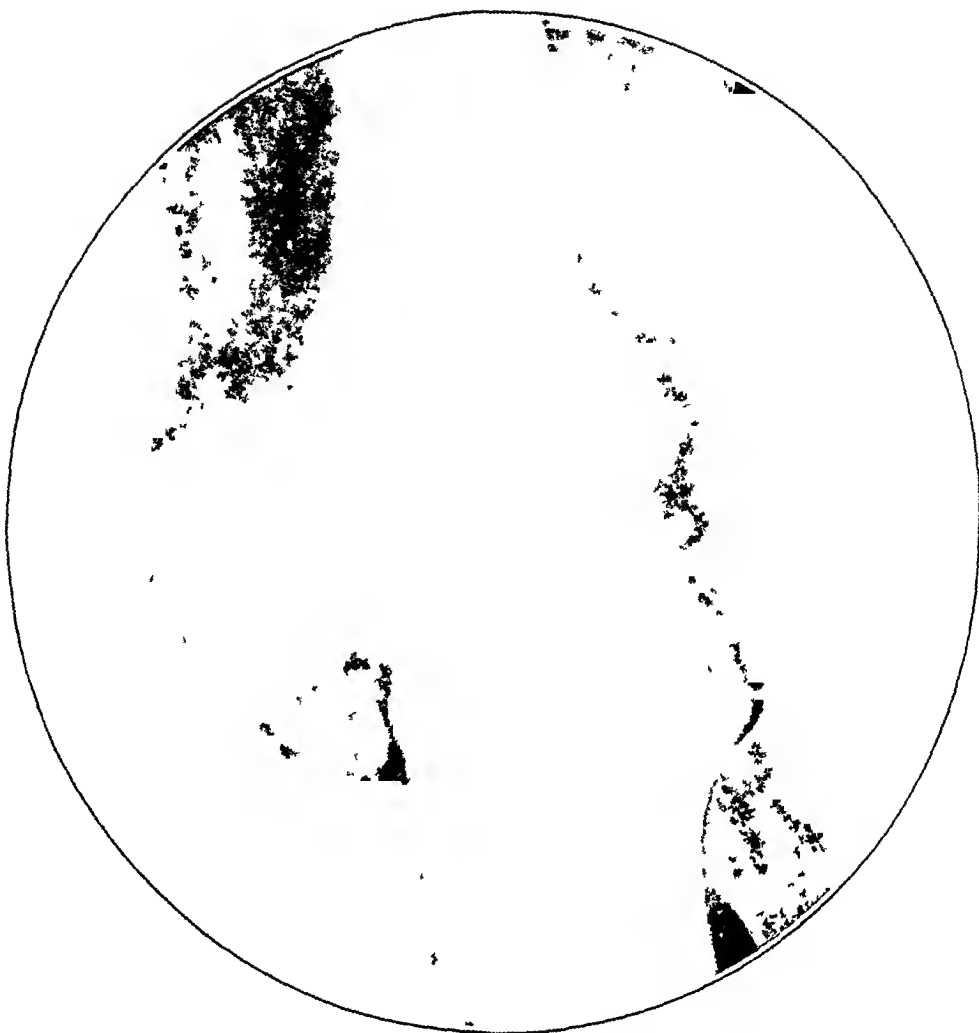


Fig 6—Patella united and held by aid of beef bone screws

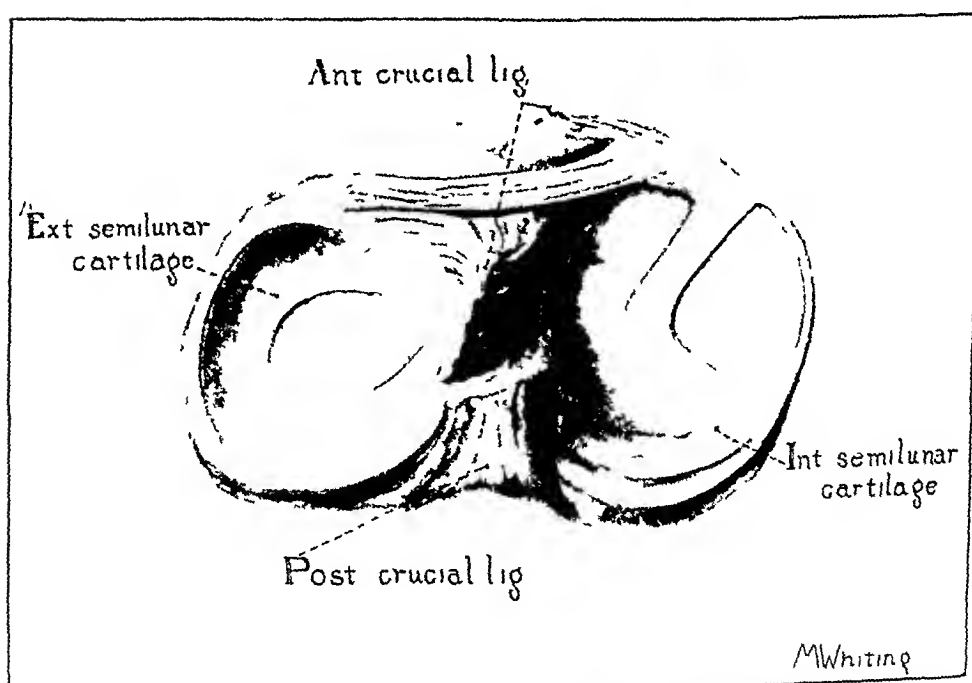


Fig 7—The common type of tear, called by Rutherford Morison the "bucket handle fracture", the loop prevents extension

screwing, twisting motion on the part of the condyle of the femur, a movement particularly liable to catch the internal semilunar cartilage. If this happens, the act of extension must be stopped at once, which is exceedingly difficult, or something will give way. The cartilage will tear from its moorings on the internal capsule, or, as usually happens, it will rip or tear in its substance. The type of tear or fracture of the cartilage depends on the manner in which it is caught.

The external semilunar cartilage, because of its loose attachment at the periphery to the capsule, has a certain laxity that the internal meniscus lacks, and usually manages to slip out of the way if threatened with crushing by the external condyle. If it is caught, however, it tears loose from its moorings before its substance tears, owing to its loose attachment to the capsule. The symptoms produced by injury to the external semilunar cartilage are variable. Extension or flexion may be prevented, depending on the exact position of the crumpled cartilage.

The story commonly told by the patient who presents himself with derangement of the knee joint attributable to the semilunar cartilages, particularly the internal, is more or less typical. The injury usually occurs during some active pursuit, either work or play. When it occurs, the knee is partially flexed and the foot everted, thus throwing the strain on the internal side of the knee joint, and, as extension is attempted, sharp pain is experienced. The patient may grasp the knee and fall to the ground, fairly writhing in pain. He often speaks of the knee as being dislocated. Effusion is fairly rapid in onset, and sometimes quite extensive, pain persists, and, unless the cartilage is reduced, may last for several days. If a physician is not available, the patient may get somebody to pull his leg, a sudden snap will be felt, and immediate relief experienced. Recurrences are common. The patient may say that during the attack a protuberance may be felt in the anterior internal aspect of the knee joint. The knee joint should not be opened if there has been but one attack, unless, after manipulation, a satisfactory reduction cannot be obtained.

A patient who has had recent locking may need an anesthetic, but this is a matter to be determined in each case. The patient should be on his back, with the thumb or finger of the surgeon placed over the anterior aspect of the internal semilunar cartilage and the knee flexed. As the knee is extended rapidly, pressure being steadily exerted over the anterior extremity of the cartilage the cartilage may slip into place. If the patient is not under an anesthetic, a great deal of reliance should be placed on whether he feels that things are right in the joint. If complete extension cannot be obtained by manipulation and the patient still insists that the joint does not feel right an exploration is justifiable and, in most cases of this character the loop type of tear will be found.



In some instances, it is difficult to determine whether the symptoms are due to damage of the internal semilunar cartilage, or of the external, but, as a rule, if the internal semilunar cartilage is involved, the symptoms are confined to the inner side of the joint, and if the external semilunar is involved, they are confined to the external side, although variations from this rule may be found.

When the lockings are so frequent as seriously to annoy the patient, surgery should be resorted to, although no set rule can be followed with regard to the number of lockings that determine this point. The anterior internal incision is the incision of choice for removing the internal meniscus, and the anterior external incision for removing the external meniscus.

The aseptic measures required in operations on the knee joint are, I believe, no more or less than those necessary for any aseptic surgery. It has been my experience that, if the rigid technic common to all properly conducted operations is observed, there is no necessity for the excessive precautions often followed in operating on the knee joint.

The knee is washed and shaved and an alcohol dressing applied the day before the operation. In the morning, the patient is brought to the operating room, the dressing removed, and the ordinary benzene and iodin preparation carried out. The operation is performed with the tourniquet. Skin towels are used, and the cartilage is carefully handled with instruments. If occasion demands, however, I have never hesitated to introduce the gloved finger into the knee joint. More than 300 mechanically deranged knee joints have been opened in the Mayo Clinic without infection. I do not believe that the technic at the time of operation is responsible for most surgical disasters due to infections, more often the cause of these infections can be traced to inefficient preparation and sterilization of the materials used. After the injured meniscus has been removed, the wound is closed in the ordinary manner, layer by layer, with silkworm and ordinary dermal sutures for the skin. A plaster-of-Paris cast is applied and worn for one week.

Another cause of mechanical derangement is the presence of osteo-cartilaginous loose bodies.<sup>6</sup> These bodies produce locking or derangements of the joint by slipping between the joint surfaces and becoming caught. As a rule, the locking is only transient, and the following effusion is less in amount and the pain less acute than in the locking due to the semilunar cartilages. These loose bodies are produced in various ways, and they are of chief interest when considered from an

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6 Henderson, M. S. Loose Bodies in the Elbow-Joint, *J. A. M. A.* **71** 177-180 (July 20) 1918, Osteocartilaginous Joint Bodies, *Railway Surg. J.* **25** 49-53, 1918, Loose Osteocartilaginous Bodies in the Shoulder-Joint, *Am. J. Orthop. Surg.* **16** 498-500 (Dec.) 1918.

etiologic point of view. There are three definite conditions causing their formation, (1) osteochondritis dissecans, (2) hypertrophic arthritis, and (3) osteochondromatosis.

In osteochondritis dissecans, there are rarely more than one or two bodies which arise from the internal condyle of the femur (Fig 8), internal and anterior to the insertion of the posterior crucial ligament.<sup>7</sup> Koenig,<sup>8</sup> in 1887, described the condition and attributed it to

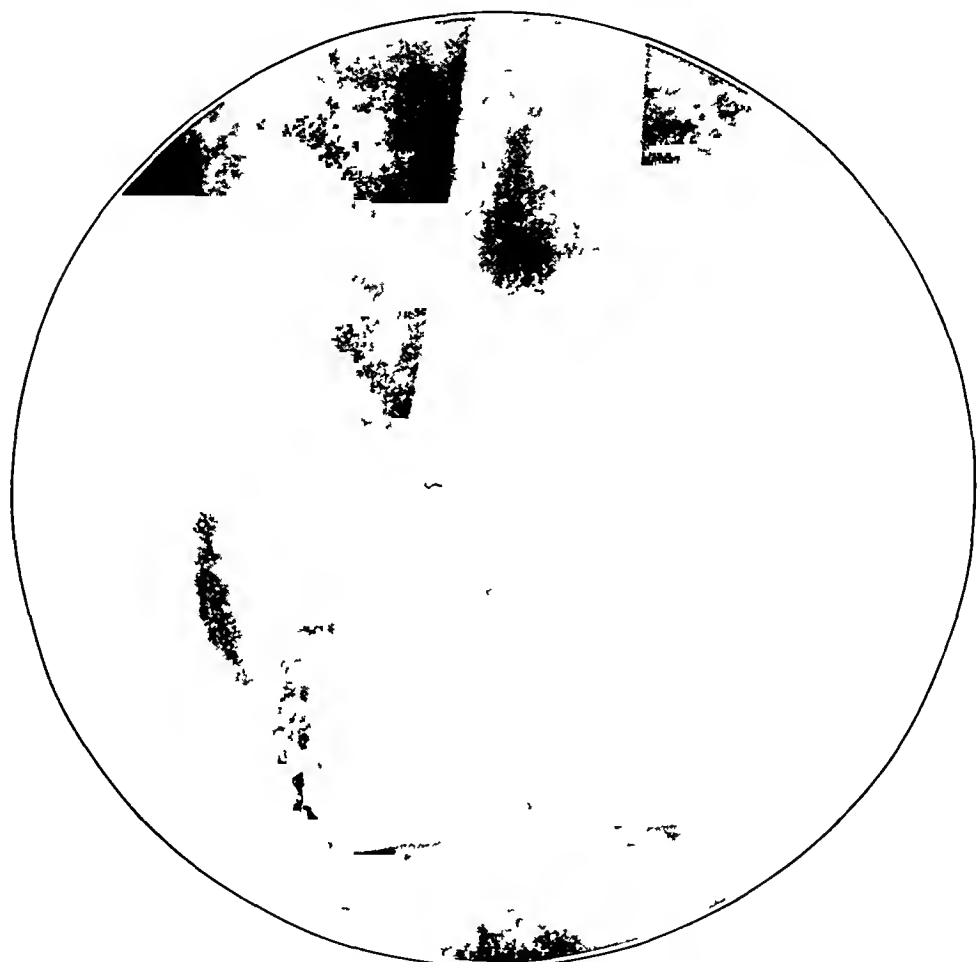


Fig 8—Osteochondritis dissecans, showing loose body lying in its cavity on the internal condyle.

a blockage in the end-artery supplying this area on the internal condyle. Other authorities have attributed it to trauma alone, but trauma per se seems an insufficient cause. In such cases the joint surfaces of the knees are peculiarly brittle, and not infrequently the condition is

<sup>7</sup> Ridlon: I. Osteochondritis Dissecans. J. A. M. A. **61**: 1777-1779 (Nov. 15) 1913.

<sup>8</sup> Koenig: Ueber freie Körper in den Gelenken. Deutsch. Ztschr. f. Chir. **27**: 90-109, 1887-1888.

present in both knees. Attention has been directed to the fact that the posterior crucial ligament definitely prevents backward displacement of the tibia on the femur, or forward displacement of the femur on the tibia. It may be that because of the constant pull thus thrown on the crucial ligament, and from it to this area, for example, in walking downstairs, this portion of the condyle becomes devitalized



Fig 9—Loose bodies due to hypertrophic arthritis

in a person with brittle joint surface, and a piece becomes loosened. This, however, is only a partial explanation. Freiberg<sup>9</sup> has recently

<sup>9</sup> Freiberg, A. H. Osteochondritis Dissecans, unpublished. Freiberg, A. H., and Wooley, P. G. Osteochondritis Dissecans, Concerning Its Nature and Relation to Formation of Joint Mice, *Am J Orthop Surg* 8:477-494, 1910-1911.

contended that the spine of the tibia, by abutting against this area, might have something to do with the production of loose bodies. Uncommonly, the external condyle may form loose bodies. Lamson<sup>10</sup> has reported one arising from the tibia. Blanco<sup>11</sup> reported a case in which hypothyroidism was present and might have been a factor.

In hypertrophic arthritis, loose bodies may be produced by the marginal osteophytic growths breaking off and dropping into the joint.



Fig 10—Multiple loose bodies due to osteochondromatosis

They wander about in the fluid and increase in size (Fig 9). If the bodies are due to hypertrophic arthritis, four, five, or even more, may be present in a joint, this is more usual in elderly persons.

10 Lamson, O F Movable Bodies in the Knee-Joint, Surg, Gynec & Obst **33** 490-493 (Nov ) 1921

11 Blanco, P Report of a Case of Loose Osteocartilaginous Bodies in the Knee-Joint, J Orthop Surg **3** 104-108 (March) 1921

In osteochondromatosis (Fig 10), the synovial membrane takes on an unusual property of forming osteocartilaginous bodies<sup>12</sup>. The bodies in such instances may reach a large number, the knee joint feels like a sack of marbles. Rare cases have been recorded in which hundreds of bodies have been removed from one joint. Why this occurs is difficult to determine. There may be an early history of trauma, but in studying the development of the knee joint in the embryo, it is found that the synovial membrane has developed in the same mesial layer of the blastema as have the cartilage and bone making up the joint, a fact that affords possible explanation. In the development of the embryo cells may have become misplaced which, later in life, take on properties not familiar to the normal cells, and produce cartilage and bone. The condition may well be likened to a benign neoplastic tumor.

The presence of the bodies alone is an indication for their removal. It is possible to do this under local anesthetic in many instances. Quite infrequently, however, they are carried in the suprapatellar pouch for years, without trouble, and it is only when they wander down into the true joint and become caught between the joint surfaces, that they cause symptoms of any consequence. Loose bodies are occasionally seen in a Charcot joint, but are of no surgical significance.

If the bodies are multiple, and their location is a little uncertain, although anterior, the split-patella incision is the incision of choice. By this means, a thorough search of the suprapatellar pouch and anterior compartment can be made. If, however, the bodies lodge in the posterior compartment, and cannot be forced through into the anterior, the posterior internal and the posterior external incisions which I<sup>13</sup> have described previously are the incisions of choice, as by this means, with the knee in a flexed position, a thorough search of the posterior capsule can be made.

#### SUMMARY

In my experience, ruptured crucial ligaments have never been the cause of significant chronic mechanical trouble in the knee joint. Probably the ligaments unite and afford stability, or patients are able to get along without them.

The treatment of old intra-articular fractures of the knee joint is practically nil, short of arthrodesis. The patient must put up with disability and pain or accept arthrodesis. Early motion is to be encouraged.

12 Whitelocke, R. H. A. Loose Bodies in the Knee. Special Reference to Their Etiology and Growth, *Brit J Surg* **1** 650-664, 1914.

13 Henderson, M. S. Posterolateral Incision for the Removal of Loose Bodies from the Posterior Compartment of the Knee-Joint, *Surg, Gynec & Obst* **33** 698-699 (Dec.) 1921.

Recurring dislocations of the patella are more common in women, and the simple reefing operation on the inner side, with lengthening on the outer side, has been as satisfactory as any procedure

In old fractures of the patella, the fragments must be brought together without tension, regardless of the amount of dissection necessary to bring this about. It is practical and safe to free the upper fragment and to use it as a graft to the lower

The semilunar cartilages are most commonly the cause of mechanical derangement, and the internal is the chief offender. This is due to the fact that the internal semilunar cartilage is firmly attached to the capsule and has not the fortunate mobility that is accorded to the external, it cannot slip out of the way and it may become nipped between the condyle of the femur and the head of the tibia

The term "loose semilunar cartilage" when applied to the internal meniscus is a misnomer. One should speak of a torn or fractured internal semilunar cartilage. The external semilunar cartilage may be spoken of as "a loose cartilage," as it is torn from its moorings and crumpled, and not necessarily fractured or torn in its substance. Repeated lockings demand the removal of the semilunar cartilages

Osteocartilaginous loose bodies may cause mechanical derangement of a more distinct type. They occur in osteochondritis dissecans, in hypertrophic arthritis, and in osteochondromatosis. The presence of these bodies, other things being equal, is cause for their removal

# GASTROJEJUNAL ULCER AN EXPERIMENTAL STUDY \*

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CHICAGO

Gastro-enterostomy has attained an important and standard position as a surgical procedure. Since the introduction of the anterior gastro-enterostomy by Wölfler and Billroth in 1881 and the posterior gastro-enterostomy by Von Hacker in 1885, the operation has been improved step by step. As a result of refinements in technique, the complications and sequelae of gastro-enterostomy have been steadily removed, until today it is regarded, generally, as a safe and dependable operation. However, the possibility of the occurrence of gastrojejunal ulcers following gastro-enterostomy is still a menace to the patient and is considered by Moynihan and others as the most important sequel of gastro-enterostomy.

In 1897 Braun reported the first case of jejunal ulcer following gastro-enterostomy. Quenu, in 1902, published the first case reported from France, and Mayo-Robson described the first case from England, in 1904. After the attention of surgeons was directed to this important condition, the number increased yearly. Gosset<sup>1</sup> was able to collect thirty-one cases in 1906. W. J. Mayo,<sup>2</sup> in 1910, had observed only three cases in 1,141 gastro-enterostomies, but Eusterman,<sup>3</sup> from the same clinic, ten years later, reported forty-seven cases in 3,700 gastro-enterostomies (1.3 per cent) performed by them and also thirty-six cases in patients who had been operated on elsewhere. Wright<sup>4</sup> was able to collect 170 cases in 1917. Rowlands,<sup>5</sup> from a detailed review of the cases reported, believed that gastrojejunal ulcer occurred in about 1.5 per cent of all gastro-enterostomies. Coffey<sup>6</sup> had 1.2 per cent of ulcers in his series of simple gastro-enterostomies. Reports from Von Eiselsberg's clinic for a period of ten years showed less than 2 per cent of ulcers following simple gastro-enterostomy. Haberer<sup>7</sup> recently reported only three jejunal ulcers in 265 simple gastro-enterostomies.

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\* From the surgical department of Rush Medical College.

1 Gosset. *Rev. de chir.* **33** 54, 1906.

2 Mayo, W. J. *Surg. Gynec. & Obst.* **10** 227, 1910.

3 Eusterman, G. B. *Minnesota Med.* **3** 517 (Nov.), 1920.

4 Wright, G. *Brit. J. Surg.* **6** 390, 1917.

5 Rowlands. *Guy's Hosp. Gaz.* **27** 149, 1913.

6 Coffey, R. C. *Surg. Gynec. & Obst.* **24** 350 (March), 1917.

7 Haberer. *Arch. f. klin. Chir.* **117** 50, 1921.

The type of operation employed has evidently had some bearing on the formation of gastrojejunal ulcer. Moynihan,<sup>8</sup> quoting from data compiled by Von Roogen, found, in 613 gastro-enterostomies, ten cases of gastrojejunal ulcer, of which six (32 per cent) occurred following 189 anterior gastro-enterostomies and four (19 per cent) following 444 posterior gastro-enterostomies. In the cases of gastrojejunal ulcer collected by Gosset, twenty followed the anterior operation and seven the posterior operation. Wright, in a series of 170 cases, found that the anterior operation had been performed in seventy-two instances and the posterior in fifty-nine. Most observers agree that these gastrojejunal ulcers are more frequent following the anterior than the posterior gastro-enterostomy. Artificial closure of the pylorus seemed to favor the occurrence of gastrojejunal ulcers. Von Eiselberg reported only four ulcers following 344 simple gastro-enterostomies, while three cases occurred in thirty-six gastro-enterostomies in which pyloric occlusion was added to the operation. Haberer reported fourteen gastrojejunal ulcers in seventy-one cases in which the pylorus was artificially closed, as against three gastrojejunal ulcers following 265 simple gastro-enterostomies. Coffey observed but one gastrojejunal ulcer in eighty-three simple gastro-enterostomies, and two in twenty-two cases in which pyloric occlusion was used.

Gastrojejunal ulcers occur in two general types. The acute perforating form is a flabby ulcer with soft walls. There is little or no reaction in the surrounding tissues and the ulcer has a tendency to rupture into the peritoneal cavity. The chronic indurative form is a hard ulcer with a rigid wall and a definite local inflammation, with the formation of adhesions. It may perforate into the colon or some other neighboring organ, or may form a localized abscess appearing in the epigastrium.

The location of the ulcer may be on the suture line or in the jejunum near the stoma. Those ulcers on the suture line may involve the stomach or jejunum or both and should be termed gastrojejunal ulcers, as suggested by Mayo. The other group which occur in the jejunum alone may be designated as jejunal ulcers. Many of them are situated in the jejunum, directly opposite the gastro-enterostomy opening. The remainder are located within a few centimeters of the stoma, usually in the efferent loop.

The cause of the formation of these ulcers following gastro-enterostomy is still unknown. Most writers believe that the factors responsible for gastrojejunal ulcers are not the same as those which produce the jejunal type.

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<sup>8</sup> Moynihan, B. Brit. M. J. 2 33 (July 12), 1919.



Gastrojejunal ulcers have generally been ascribed to errors in technique. Nonabsorbable sutures have been found embedded in these ulcers by Mayo,<sup>9</sup> Moynihan, Wright, Poole,<sup>10</sup> Hutchison,<sup>11</sup> Gronnerud,<sup>12</sup> and others. They believe that the use of silk or linen sutures, which are frequently retained in the bowel wall for a long period of time, are responsible for the occurrence of these ulcers. Paterson,<sup>13</sup> however, does not believe that the indictment of nonabsorbable sutures is justifiable. Woolsey<sup>14</sup> has reported a case in which the patient had all the symptoms of a gastrojejunal ulcer. At operation a loop of silk was found dangling from the edge of the stoma, but there were no signs of an ulcer. Removal of this suture cured the patient. Marginal ulcers have been reported by Delore and Couvert<sup>15</sup> in cases in which catgut alone had been used. Wright found one ulcer in fourteen cases following the use of a button for intestinal anastomosis. Inaccurate coaptation of the mucous membrane is regarded as a cause by Paterson, Moynihan and Roeder.<sup>16</sup> Delore and Couvert,<sup>15</sup> however, have reported five cases of marginal ulcer following gastro-enterostomies in which they had used a three row suture, with careful approximation of the mucosa.

Bruising of the tissues by clamps is given as a cause by Moynihan<sup>17</sup> and Ivy.<sup>18</sup> Paterson<sup>13</sup> disagrees with this idea, as many of these ulcers have occurred in places that were not touched by the clamps. Delore and Couvert did not use clamps in the five cases referred to above, but all the ulcers in their cases were of the marginal type. Paterson and Delore and Couvert believe that the symptoms of gastrojejunal ulcer appear too long after operation to be due to the traumatism of clamps. It is well to remember, however, that many gastric and duodenal ulcers have long periods of remission during which they produce no symptoms.

Gosset<sup>1</sup> believed that pyloric obstruction with dilatation of the pyloric end of the stomach tended to produce these ulcers. More recently Haberer<sup>7</sup> and Von Eiselsberg have shown that the percentage of gastrojejunal ulcers following artificial pyloric closure is many times greater

9 Mayo, W. J. *Boston M. & S. J.* **170** 149, 1914, *Ann. Surg.* **57** 691, 1913, *ibid.* **55** 398, 1912, *ibid.* **60** 220, 1914.

10 Poole, E. H. *Ann. Surg.* **66** 122, 1917.

11 Hutchison, R. *Brit. M. J.* **1** 535 (May 3) 1919.

12 Gronnerud, P. *Ann. Surg.* **66** 177 (Aug.) 1917.

13 Paterson, H. J. *Internat. J. Surg.* **33** 138, 1920.

14 Woolsey. *Ann. Surg.* **66** 121, 1917.

15 Delore and Couvert. *Rev. de chir.* **58** 28, 1920.

16 Roeder, C. A. *The Relation of Surgical Technique to Gastrojejunal Ulcer*, *Arch. Surg.* **3** 622 (Nov.) 1921.

17 Moynihan, B. *Tr. Am. Surg. A.* **21** 135, 1903.

18 Ivy, A. C. *Studies on Gastric and Duodenal Ulcer*, *J. A. M. A.* **75** 1540 (Dec. 4) 1920.

than the percentage following gastro-enterostomy alone. Haberer believes that closing the pylorus stimulates the action of the acid producing pyloric portion of the stomach, resulting in secondary ulcer formation about the gastro-enterostomy opening. He strongly advocates performing a pylorectomy and asserts that gastrojejunal ulcers do not occur after this operation.

Hematoma formations at the time of operation, due to needle pricks, clamps or digital bruising, are mentioned as a cause by Moynihan and Mayo. Dean Lewis believes that marginal ulcers are usually due to hematomas that occur on the suture line.

Hyperchlorhydria and excessive gastric secretion are given a prominent place in the causation of secondary ulcers, especially of the jejunal type, by most observers. Paterson says that this destructive type of gastric juice may be a persistence of the kind present before operation, or it may be due to a lack of neutralization if the biliary and pancreatic juices are directed away from the stomach by operations. Bastedo<sup>19</sup> asserts that the neutralizing action of the bile and pancreatic fluid is not very great, as shown by observations made in a case of cholecyst-gastrostomy. Wilensky and Crohn have found the highest acidity when the amount of bile was greatest in the stomach. Many writers believe that the highly acid gastric juice acts as a chemical trauma to the alkaline jejunal membrane, especially in those cases in which the ulcer forms opposite the stoma. Paterson points out the fact that jejunal ulcers are more frequent following anterior gastro-enterostomy in which so often an entero-enterostomy has also been performed. He also calls attention to the fact that the gastric acidity is highest in cases of duodenal ulcer and that jejunal ulcers occur most often following gastro-enterostomies performed for the relief of duodenal rather than gastric ulcers.

The impression derived from the literature is that errors in technic are the principal causes of gastrojejunal ulcers. Hyperchlorhydria and excessive gastric secretion are thought to play a part in the production of gastrojejunal ulcers, but they are regarded as the essential cause of jejunal ulcers.

In order to obtain more definite information in regard to the cause or causes of gastrojejunal ulcers following gastro-enterostomies, a series of experiments was performed on dogs. From the literature it was found that Watts,<sup>20</sup> in 1903, reported two ulcers which he found in the jejunum of a dog, three months after an anterior gastro-enterostomy had been performed. He had used two rows of silk sutures and some of the silk was still dangling in the stoma, but the ulcers were not on the suture line but in the jejunum, opposite the stoma. There was no

19 Bastedo, W. A. *Am J M Sc* **160** 491 (Oct.) 1920

20 Watts. *Bull Johns Hopkins Hosp* **14** 191, 1903

silk found in either of the ulcers. Cannon and Blake<sup>21</sup> working with cats, found an occasional jejunal ulcer following gastro-enterostomy. The ulcers were located opposite the stoma or near it. Ivy<sup>18</sup> has reported five ulcers which he found in forty dogs that had been subjected to pylorotomy and gastroduodenostomy. In three cases the ulcers were of the acute perforating type and occurred within five weeks after operation. The ulcers in the other two cases were of the chronic variety and were found eight and eleven months, respectively, after operation. None of the ulcers were located on the suture line.

All five of these dogs had vomited a great deal and had become severely emaciated. Ivy believes that the ulcers were due to cachexia from improper diet and also to the use of clamps. He says that no ulcers have occurred in dogs which he has since operated on, if he has carefully regulated their diet and used clamps merely for approximation and not for hemostasis. Gromierud states that he has found ulcers in dogs following gastro-enterostomy but gives no particulars in regard to them. He attributes their formation to nonabsorbable sutures and the use of clamps. Borszky<sup>22</sup> narrowed the pylorus and performed a gastro-enterostomy in twelve dogs. They were given 1 ounce (30 cc) of diluted hydrochloric acid, daily. He found a jejunal ulcer in only one of the twelve dogs.

Following out this line of work, Exalto<sup>23</sup> divided the duodenum at the pylorus in seven dogs, closed both ends and then performed a posterior gastro-enterostomy, using clamps and three rows of sutures. He put all seven dogs on a meat diet and gave six of them 50 cc of diluted hydrochloric acid, daily. None of these dogs developed an ulcer. He repeated these operations in seven other dogs, but in addition he divided the jejunum proximal to the anastomosis and closed both ends of the sectioned bowel. He then anastomosed the proximal loop to either the small or large bowel near the cecum, thus diverting the biliary and pancreatic fluid entirely away from the gastro-enterostomy. Two of the dogs were fed on a mixed diet and the other five were given a meat diet and 50 cc of diluted hydrochloric acid daily. Six of the dogs showed a jejunal ulcer at necropsy. One of the dogs that had been fed on meat and diluted hydrochloric acid showed no evidence of an ulcer. In four animals, the ulcers were multiple. All the ulcers were located in the jejunum opposite the stoma, except in one case in which the ulcer was located in the blind end of the jejunum.

In our experiments, gastro-enterostomies were performed on dogs by various methods, under ether anesthesia. An aseptic technic was

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21 Cannon and Blake. *Ann Surg* **41** 686, 1905.

22 Borszky. *Beitr f klin Chir* **57** 56, 1908.

23 Exalto. *Mitt a d Grenzgeb d Med u Chir* **23** 13, 1911.

carried out in every case and clamps were used, but not for hemostasis. The pylorus was not closed in any of the operations. If the dogs did not die in the meantime, they were allowed to live several months and were then killed.

#### REPORT OF EXPERIMENTS

GROUP 1—A posterior gastro-enterostomy was performed on five dogs, using a two row continuous catgut suture. In two of the dogs, before taking the final row of stitches, a hematoma was produced along the suture line by piercing a blood vessel with a needle subperitoneally, near the cardiac angle of the anastomosis. One of the three dogs without hematoma formation died on the third day after operation from a perforation along the suture line. The other two dogs died of respiratory infection, twenty-two and forty-seven days after operation. There was no ulcer found in either of these animals at necropsy. Of the two dogs in which a hematoma had been produced at operation, one died of a respiratory infection twenty-six days after operation. At necropsy a very definite ulcer was found in the jejunum, bordering on the suture line (Fig 1), at the cardiac angle of the stoma. The ulcer was of the chronic indurative type, 6 by 15 mm in size, and occupied the position of the hematoma made at the time of operation. The anastomosis otherwise was perfectly healed and there were no adhesions. The other dog died of peritonitis, 185 days after operation. At necropsy, a perforated ulcer was found in the jejunum, bordering on the stoma at the cardiac angle of the anastomosis where the hematoma had been located (Fig 2). The ulcer was 8 by 10 mm in diameter, and had a hard, thin edge.

GROUP 2—Five dogs were subjected to a posterior gastro-enterostomy, using three rows of continuous catgut suture. Hematomas were made at the pyloric angle of the anastomosis in two of the dogs by the method described above. The animals operated on without hematoma formation died of respiratory infections, eleven, twelve and eighteen days, respectively, after operation. The anastomosis was found to be intact and patent in every case at necropsy. The peritoneal cavity was clean. The edge of the stoma was healed, except at the angles where healing was not yet complete. There was no ulcer in any of these dogs. Of the two animals in which a hematoma had been made at operation, one died of distemper, ninety days after operation. The other animal was killed in a dog fight, twenty-two days after operation. Necropsy in both cases revealed perfect healing of the anastomosis. The places where the hematomas had been made appeared entirely normal. There was no evidence of an ulcer in the stomach or jejunum of either of these dogs.

GROUP 3—Five dogs were subjected to a posterior gastro-enterostomy by the two row suture method. Continuous catgut was used for the inner row and continuous silk for the outer row. In two of the dogs a hematoma was made by the method already described, about midway between the angles of the anastomosis, in one case on the jejunum and in the other on the stomach. These hematomas were inoculated with 1 c c of a suspension in salt solution of virulent colon bacilli. Of the three animals operated on without hematoma formation, one died thirty-one days after operation. At necropsy a large hair ball was found blocking the outlet of the stomach. The anastomosis was perfectly healed, with no signs of ulcer formation. The other two dogs died of skin diseases, 138 and 158 days, respectively, after operation. The anastomosis

was well healed at necropsy, although silk threads were dangling from the margins of the stoma, especially at the angles, in both cases. In neither animal was there any sign of an ulcer formation. The two animals with hematomas, which had been inoculated with colon bacilli at the time of operation, were killed, 139 and 137 days respectively, after operation. A necropsy in both cases demonstrated that the anastomosis was healed but that silk was dangling in the bowel from the margin of the stoma. The hematoma had disappeared without leaving any perceptible scar. There were no ulcers.

GROUP 4—This consisted of five dogs in which the experiment described above was repeated, except that a three row suture was employed in the anastomosis instead of a two row suture. Continuous catgut was used for the two inner rows and continuous silk for the outer row.

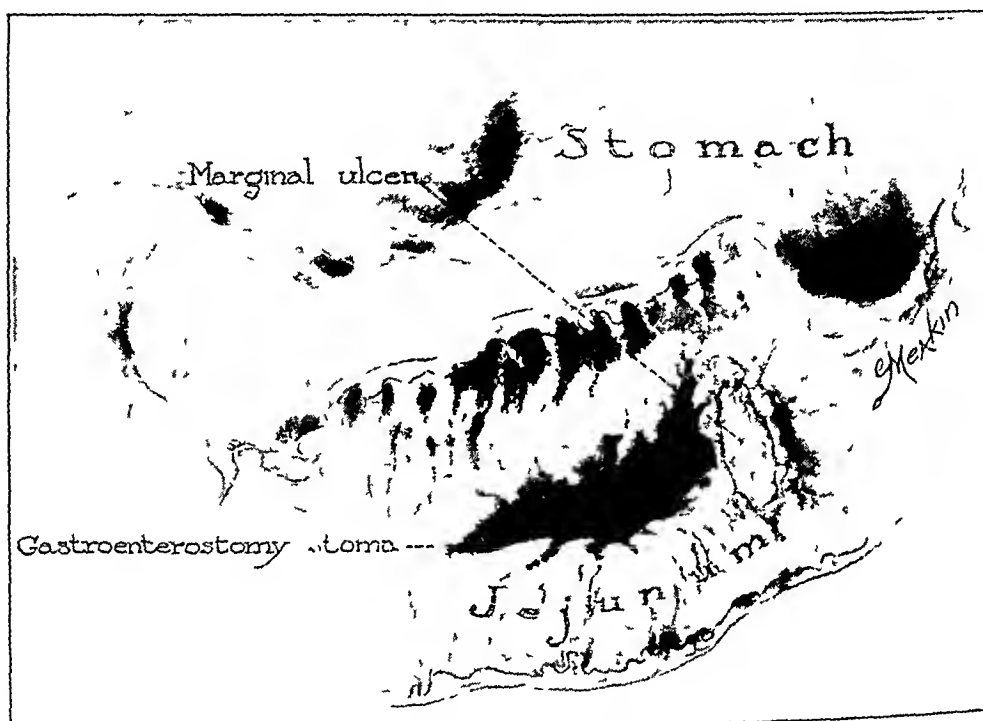


Fig 1—Gastrojejunal ulcer in a dog, twenty-six days after operation

Of the three dogs operated on without hematoma formation, two died of distemper 146 and 221 days, respectively, after operation. The third animal died thirty-three days after operation, probably from a hair ball in the stomach. Necropsy in these three dogs was negative in regard to ulcer formation. The anastomoses were well healed. Silk was dangling from a margin of the stoma in the dogs that lived 146 and 221 days, respectively, after operation. Hematomas were made in the other two dogs in this group, they were also inoculated, just as in Group 3. One of these dogs died from an infection of the abdominal wound, nine days after operation. At necropsy there were omental adhesions about the site of the hematoma on the jejunum. The mucosa appeared to be healthy everywhere, and healing of the anastomosis had progressed normally. The other animal died from a respiratory infection, 123 days after operation. The anastomosis was well healed, with no evidence remaining of the hematoma. The silk suture had eroded into the bowel in several places but there was no ulcer formation.

GROUP 5—This comprised eight dogs that were subjected to a posterior gastro-enterostomy, using the two row suture method. Continuous catgut was employed for the inner row and interrupted silk for the outer row. In addition, a hematoma was made in four of the animals by the subserous needle puncture of the vessels. The hematoma in two of the dogs was placed at the cardiac angle, in one on the stomach and in the other on the jejunal side. In the other two dogs, the hematoma was made at the pyloric angle, in one on the stomach and in the other on the jejunal side. Of the four dogs operated on without hematoma formations, one died from an infection of the abdominal wall, four days after operation. The abdominal cavity was clean at necropsy and the anastomosis was intact. There was no sign of an ulcer. Another dog died of a respiratory infection, forty-one days after operation. The anastomosis was well healed. Silk was present in the jejunum in two places,

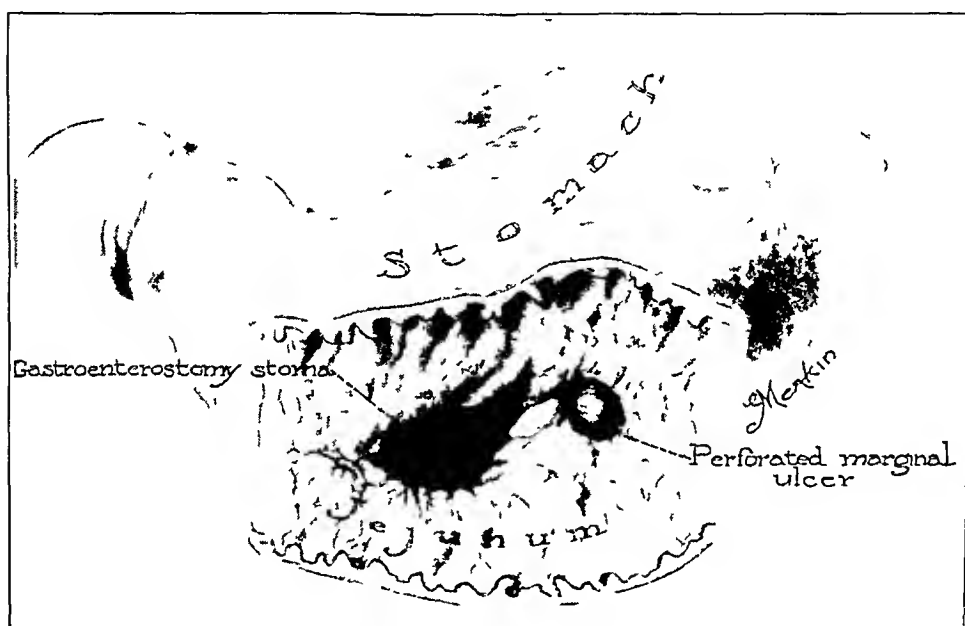


Fig 2—Perforated gastrojejunal ulcer in a dog, followed by death from peritonitis, 185 days after operation

but there was no evidence of ulcer formation. A third dog died of respiratory infection, forty-six days after operation. The anastomosis appeared to be perfectly healed. There was no ulcer present, although a silk suture was present in the jejunum in one place. The fourth dog was killed, 270 days after operation. The anastomosis was perfectly healed. There was no silk showing on the mucosa, and there was no sign of an ulcer.

Of the four dogs operated on with hematoma formation, one died of respiratory infection, 125 days after operation. The anastomosis was well healed. There was no silk showing on the mucosa. The hematoma had entirely disappeared and there was no sign of an ulcer. Another dog was killed, eighty-nine days after operation. The anastomosis was well healed. Silk had eroded into the jejunum in three places. The hematoma had disappeared and there was no sign of an ulcer. A third dog died of distemper eighteen days after operation. The anastomosis was almost healed and no silk showed on the mucosa. At the site of the hematoma which had been made on the

stomach at the cardiac angle, there was a small area of submucous hemorrhage, with some erosion of the mucosa but no definite ulcer formation. The fourth dog died of a skin disease, 200 days after operation. The anastomosis was thoroughly healed. At the site of the hematoma on the jejunum at the cardiac angle of the stoma, there was a marginal ulcer 7 by 15 mm in size (Fig 3). The edge of the ulcer was round, elevated and well defined. The base was clean and did not show any silk.

GROUP 6—This consisted of thirteen dogs that were subjected to a posterior gastro-enterostomy. The anastomosis was made with two rows of continuous silk sutures. In five of the animals, the outer suture row when completed was tied and the ends of the suture cut off about an inch (25 cm) beyond this and tied into a knot. The loop of two silk threads, an inch (25 cm)

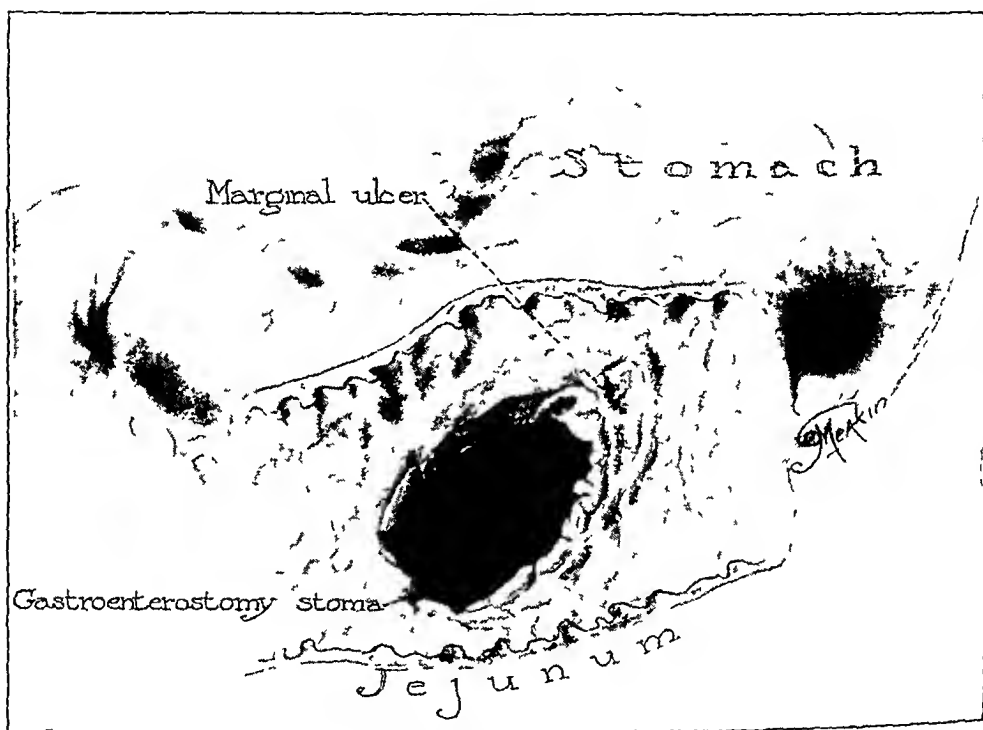


Fig 3—Gastrojejunal ulcer in a dog, 200 days after operation

long with a knot at the end, was pushed into the bowel between the edges of the anastomosis and allowed to dangle in the lumen. Of these five dogs, two died of respiratory infection twenty-two and thirty-one days, respectively, after operation, two died of skin disease, twenty-six and thirty-seven days, respectively, after operation, and one died of a large hair ball in the stomach, forty-six days after operation. The anastomosis was healed in all five animals, except at one or more places where the inner thread was still adherent, although the greater part of the suture was hanging free in the bowel. The knotted end of the outer suture that had been pushed into the bowel was dangling there. In two instances, the knot had been made much larger by hair that had collected on it. Two of the dogs had had tarry stools, and old blood was present in the jejunum near the stoma. There was no evidence of ulcer formation in any of the five animals. Of the other eight dogs in this group, three died of respiratory infection, ten, seven and seventeen days respectively, after operation. The anastomoses appeared to be healing normally.

and there were no signs of ulcer formation. One dog was killed in a fight, eighteen days after operation. The specimen was too badly mutilated to be of any value. Another dog died of evisceration, as a result of an infected abdominal wound, fifty-three days after operation. The anastomosis was healed in this animal except at one place where the inner suture thread was still adherent. There was no ulcer present. Another dog died of distemper, 127 days after operation, and the remaining two dogs died of chronic skin diseases, 154 and 208 days, respectively, after operation. In the last three animals, the anastomoses were found to be well healed. The inner suture thread had entirely disappeared, but the outer suture row had eroded into the bowel in one or more places. There was no evidence of ulcer formation in any of these dogs.

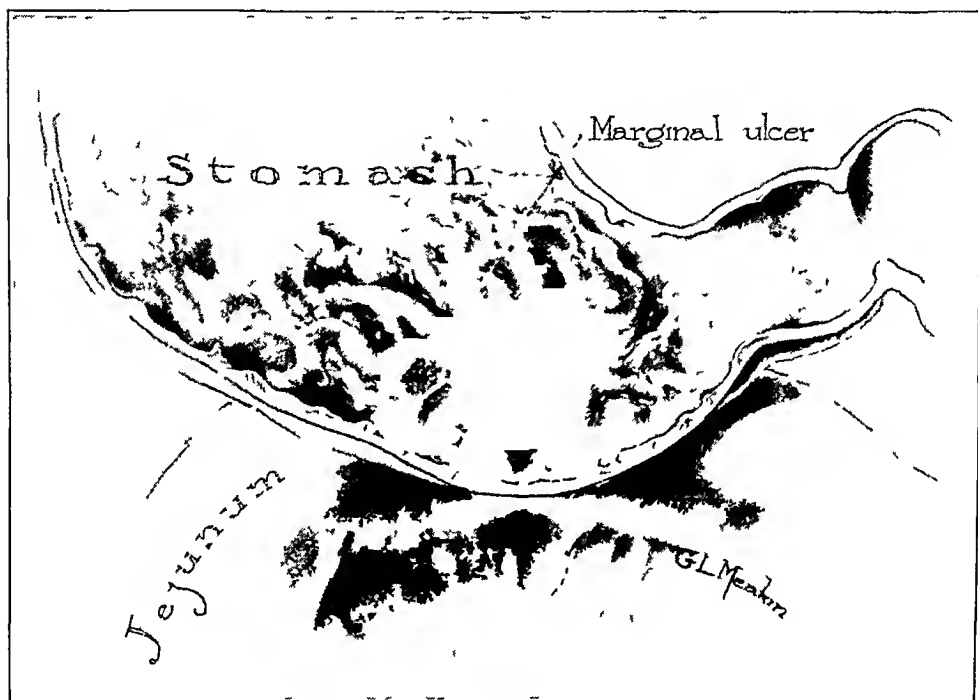


Fig 4—Gastrojejunal ulcer in a dog, 100 days after operation

GROUP 7—This comprised five dogs that were subjected to an anterior gastro-enterostomy, using two rows of continuous catgut sutures. In two of the dogs a hematoma was made in the jejunum near the suture line, at the pyloric angle in one animal, and at the cardiac angle in the other. One dog died of pneumonia, four days after operation, another escaped from the laboratory, thirty-seven days after operation, a third was killed, 122 days after operation. Of the two dogs with hematoma formation, one died of a respiratory infection, twenty-six days after operation, and the other was killed ninety days after operation. In the four animals on which we were able to perform a necropsy, healing of the anastomosis was complete or was progressing normally. The hematoma had disappeared and there was no ulcer present.

GROUP 8—This consisted of five dogs that were subjected to an anterior gastro-enterostomy, using three rows of continuous catgut sutures. In two of the dogs, hematomas were made as in the preceding experiment. One dog



died of pneumonia, nine days after operation, another died of distemper, sixteen days after operation, and the third was killed, 120 days after operation. The two dogs in which a hematoma had been made died of respiratory infection, twenty-four and thirty-six days, respectively, after operation. In these five dogs, healing of the anastomosis was either complete or progressing normally. The hematomas had disappeared and there was no ulcer formation.

GROUP 9—In this group there were five dogs that were subjected to a gastro-enterostomy and an entero-enterostomy of the afferent and efferent loops. A two row continuous catgut suture was used in making both anastomoses.

#### RESULTS OF EXPERIMENTAL STUDY OF GASTROJEJUNAL ULCER

Group	Operation	Suture Material	Hema toma	Ulc er	Without Hema toma	Ulc er
1 5 dogs	Posterior gastro enterostomy, two row suture	Continuous catgut, both rows	2	2	3	0
2 5 dogs	Posterior gastro- enterostomy, three row suture	Continuous catgut, three rows	2	0	3	0
3 5 dogs	Posterior gastro- enterostomy, two row suture	Continuous catgut, inner row, continuous silk, outer row	2 Inocu lated	0	3	0
4 5 dogs	Posterior gastro enterostomy, three row suture	Continuous catgut, inner two rows, con tinuous silk, outer row	2 Inocu lated	0	3	0
5 8 dogs	Posterior gastro enterostomy, two row suture	Continuous catgut inner row, interrupted silk, outer row	4	1	4	0
6 13 dogs	Posterior gastro- enterostomy, two row suture, five with knot in bowel	Continuous silk, both rows	0	0	13	0
7 5 dogs	Anterior gastro enterostomy, two row suture	Continuous catgut, both rows	2	0	3	0
8 5 dogs	Anterior gastro- enterostomy, three row suture	Continuous catgut, three rows	2	0	3	0
9 5 dogs	Anterior gastro- enterostomy with entero enterostomy, two row suture	Continuous catgut, both rows	0	0	5	1
10 7 dogs	Anterior gastro enterostomy with entero enterostomy, two row suture	Continuous silk, both rows	0	0	7	0

One dog died of hemorrhage the day after operation. Another dog died of pneumonia, three days after operation. A third dog died from an unknown cause, eighty-six days after operation. A necropsy on this animal revealed the fact that both anastomoses were perfectly healed, with no signs of an ulcer in the stomach or bowel. The fourth dog developed skin trouble and died from infection produced by scratching, 104 days after operation. A necropsy on this animal disclosed perfect healing of both anastomoses and no evidence of ulcer formation. The fifth dog lived 100 days after operation. A very large hair ball was found in the stomach of this animal after death.

Bordering on the stoma at the cardiac angle, there was a definite hard ulcer, 7 by 7 mm in diameter, lying between the rugae on the gastric mucosa (Fig 4)

GROUP 10—This consisted of seven dogs that were subjected to an anterior gastro-enterostomy with an entero-enterostomy, as in the previous experiment. A two row continuous silk suture was used instead of catgut in making the anastomoses. One dog died of pneumonia, six days after operation. The anastomosis at necropsy appeared to be healing normally. Another dog died of exposure to cold the day after operation. A third dog probably died because of a bundle of worms that blocked the stoma. He was found dead, thirty-six days after operation. A fourth animal died of distemper, ninety-eight days after operation. The fifth and sixth dogs were killed, sixty-one and 121 days, respectively, after operation. A seventh dog died of peritonitis, forty-one days after operation. In the last five dogs, necropsy demonstrated that the anastomoses were well healed, except at two or three places about each stoma, where the inner thread was still attached. The outer thread had ulcerated into the bowel at several places, especially at the cardiac angle where the knot was located. There was no evidence of definite ulcer formation in the stomach or bowel of any of these animals.

#### COMMENT

In this series of experiments, sixty-three dogs were subjected to a gastro-enterostomy. Of this total number, one escaped from observation, the thirty-seventh day after operation, another died of hemorrhage, the second day after operation, and a third died, the day after operation, from exposure to cold. These three animals may be omitted from our calculations, leaving sixty dogs to be considered in our observations. A definite gastrojejunal ulcer was found in four (6.66 per cent) of these sixty animals. In every case the ulcer was a fairly large, solitary lesion, somewhat indurated and well defined. Macroscopically, it showed all the characteristics of a chronic ulcer. This diagnosis was confirmed by microscopic sections, which showed a definite ulcer border with erosion of the mucosa and muscularis mucosa. In the submucosa which formed the floor of the ulcer, there was definite round-cell infiltration.

After reviewing our work, certain factors were considered in relation to their influence on the production of these marginal ulcers.

Some years ago, Cannon and Blake<sup>21</sup> pointed out that the anterior gastro-enterostomy in animals like the dog or cat was the nearest approach to the posterior operation in man. In view of that fact, our results correspond to numerous observations in man in which gastrojejunal ulcers have been found much more frequently following the anterior than the posterior operation. Three of the ulcers in our series occurred after posterior gastro-enterostomy and only one after an anterior gastro-enterostomy. In this one instance, the ulcer was located on the gastric mucosa bordering on the stoma. It was the only one of

the four ulcers that formed on the stomach side of the opening. At necropsy on this animal, a very large hair ball was found occluding the pylorus and the gastro-enterostomy stoma. It is very probable that the hair ball, impregnated with dirt and fragments of bone, was the cause of the ulcer.

Diverting the flow of bile and pancreatic secretion from the stomach by means of an entero-enterostomy did not seem to have any definite effect on ulcer production. Only one dog in which we employed this procedure developed an ulcer. That particular ulcer is the one that was probably due to the grinding action of the hair ball, as has just been stated. Diverting the alkaline secretion would seem to have been a minor factor at the most.

Hematoma formation appeared to have exerted a marked influence in the production of these ulcers. In three dogs, an ulcer formed at the site of a hematoma which had been placed on the jejunal border of the stoma. In no instance did an ulcer form at the position of a hematoma placed on the gastric side of the stoma. From this observation, it would seem that the gastric mucosa was more resistant to the devitalizing action of a hematoma than the jejunal mucosa. In those cases in which an ulcer did not form at the site of the hematoma, healing progressed normally and the hematoma was absorbed. Inoculating the hematomas with virulent colon bacilli produced only negative results. In every case in which the inoculation was performed, the wound progressed to normal healing without ulcer formation. The dogs evidently had a strong resistance to colon bacilli. In connection with this question of hematomas, it is interesting to note that all of the ulcers occurred in cases in which the two row suture method had been used, although hematomas were made in an equal number of dogs operated on by the three row method. It would seem logical to believe that the middle row of sutures prevented the hematoma from extending to the mucosa. In addition, as Roeder has recently shown, the three row suture method provides better hemostasis and more careful apposition of the mucous edges. It tends to early healing by avoiding the strangulation and subsequent sloughing of the mucosa that occur when a mattress stitch, embracing all the coats, is used to control bleeding. Roeder shows that the scar after the three row suture is much smaller and softer.

Another interesting observation was that all four of our ulcers were located at the cardiac angle of the anastomoses. This corresponds to the clinical findings of a number of surgeons in regard to these marginal ulcers in man. The cardiac angle is usually the place where the last stitches are taken in performing a gastro-enterostomy and where the knots are placed. With a two row suture, it is frequently very difficult

to secure good apposition at this point, and a poorly placed suture permits gaping of the mucous edges and hematoma formation. In addition, the cardiac angle is the place that sustains the greatest strain from the long dependent efferent loop, so that healing at this point is most liable to be delayed on account of interference with the blood supply. The three row suture method permits good suturing at this angle where it would seem to be especially needed.

Nonabsorbable suture material has been very generally blamed by surgeons for producing marginal ulcers. According to Rogers, Senn showed experimentally that all nonabsorbable suture material used in performing a gastro-enterostomy ultimately sloughed into the bowel. This was observed in our animals in which silk from one or both rows was found eroding into the bowel or dangling from the edge of the stoma, months after the operation. Despite this fact, all of our ulcers except one occurred in animals in which only ~~catgut~~ catgut had been used. In that one case, an ulcer occurred where catgut had been used for the inner row and interrupted silk for the outer row. At necropsy the interrupted silk sutures seemed to have disappeared entirely in the 200 days that had intervened after operation. There was no silk embedded in the base or edge of the ulcer. These results in animals would seem to agree with those of a number of observers who have found gastrojejunal ulcers in man when catgut alone had been used. Our experiments fail to show any causal relationship between non-absorbable suture material and gastrojejunal ulcers. However, they emphasize the fact that nonabsorbable sutures ultimately slough out, but the process often extends over months. Interrupted silk sutures used in our animals sloughed out much more rapidly than the continuous silk sutures. Dangling knots, even when enlarged by hair which became entangled, did not produce an ulcer in any instance.

Clamps were used to approximate the stomach and jejunum in every anastomosis. As the ulcers we obtained occurred on the edge of the stoma and not on the line of application of the clamps, it is impossible to believe that clamps had any influence on our results.

The effect of pyloric occlusion on the formation of gastrojejunal ulcers has not been considered in this report, as the pylorus was allowed to remain patent in every case. This factor will be dealt with in a subsequent paper.

#### CONCLUSIONS

From this series of experiments on dogs, these conclusions have been drawn:

1. Gastrojejunal ulcers occur in dogs following gastro-enterostomy with a patent pylorus.

2 These ulcers have a tendency to perforate and are similar in other respects to gastrojejunal ulcers found in man

3 They seem to occur following hematomas that affect the jejunal mucous membrane at the cardiac angle of the stoma where suturing and hemostasis are imperfect

4 The imperfections in technic at this place may be avoided by the use of the three row suture method

5 Hematomas situated at other places along the suture line may be absorbed and produce no damage

6 Gastrojejunal ulcers occur independent of the kind of suture material employed

7 Gastrojejunal ulcer in dogs is more frequent following the posterior operation, which corresponds to the anterior operation in man

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# MESENTERIC VASCULAR OCCLUSION \*

LEO BRADY, M D

BALTIMORE

Reports of cases of mesenteric thrombosis and embolism treated successfully by surgical intervention no longer receive the widespread comment that in 1895 greeted Elliot's article on the first instance of recovery of a patient with intestinal infarction. However, even today the mortality in these cases is very high, and reports of surgical successes are still of considerable interest.

The first instance of occlusion of the mesenteric vessels seems to have been reported by Tiedemann<sup>1</sup> in 1843, and four years later Virchow<sup>2</sup> explained the pathology of the condition. In 1875 Litten described fairly accurately the clinical picture. From that time until 1895, when Elliot<sup>3</sup> reported his famous case, there were no great advances made in the diagnosis or treatment of this condition. Jackson, Porter and Quinby,<sup>4</sup> in 1904, published what was probably the most complete study made on this subject up to that time. Trotter,<sup>5</sup> in 1913, reported six new cases and analyzed the 360 reports of cases already in the literature. The only one of his six patients that recovered did so without operation, which, of course, makes the accuracy of the diagnosis doubtful. Ross,<sup>6</sup> in 1920, reported six new cases with one operative success. Although in the case reported by Ross of the patient that recovered, thrombosis of a branch of the superior mesenteric artery was noted at operation and there was some hemorrhage into the mesentery, the segment of bowel involved was in fairly good condition and no resection was performed. This was undoubtedly one of the rare instances of sufficient collateral circulation developing after a mesenteric thrombosis to prevent the formation of an intestinal infarction. The last article on this subject appeared in July, 1921, consisting of

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\* From the Gynecological Department of the Johns Hopkins Hospital and the Johns Hopkins University Medical Department.

1 Tiedemann. Von d Verengerung u Schliessung d Pulsadern in Krankheiten, Heidelberg and Leipzig **131** 1843.

2 Virchow. Gesamte Abhandlungen pp 338 420, 451.

3 Elliot, J W. The Operative Relief of Gangrene of the Intestine Due to Occlusion of the Mesenteric Vessels, *Ann Surg* **21** 1895.

4 Jackson, J M, Porter C H, and Quinby, W C. Mesenteric Embolism and Thrombosis, *J A M A* **42** 1469 (June 4), 1904, *ibid* **43** 25 (July 2), 110 (July 9), 183 (July 16), 1904.

5 Trotter, L B C. Embolism and Thrombosis of the Mesenteric Vessels, Cambridge University Press, 1914.

6 Ross, G G. Mesenteric Thrombosis, *Ann Surg* **72** 121 (July), 1920.

a report by Loop<sup>7</sup> of nine cases in which operation was performed. Eighteen inches (45.7 cm) of intestine was removed and a lateral anastomosis was performed on the one patient in this series that survived. At the present time there are records in the literature of about 500 cases of mesenteric thrombosis and embolism with not more than thirty-five recoveries. Of the forty-seven patients operated on in Jackson's series only four survived.

Recently I treated a patient with intestinal infarction that survived. My interest in this subject being aroused I decided to go over the records in the Johns Hopkins Hospital of all the patients with mesenteric thrombosis and embolism. In all I found fourteen instances of mesenteric vascular occlusion. However, in three cases there was no formation of an intestinal infarction and the mesenteric thrombosis was discovered only at necropsy. That in a slowly developing thrombosis of the mesenteric vessels the collateral circulation may develop sufficiently rapidly to prevent the formation of an infarction has long been known. To quote from Welch's<sup>8</sup> article in Allbutt's System of Medicine: "Intestinal infarction is not the imperative result of occlusion of the superior mesenteric artery as infarction is of occlusion of branches of the splenic and renal arteries." Welch quotes Chiene's<sup>9</sup> case of a woman, 65 years old, with an aneurysm of the abdominal aorta and complete obliteration of the celiac axis and both mesenteric arteries, who had an adequate collateral circulation through the greatly distended extraperitoneal anastomosing arteries. But Welch says later, "The rapid and complete closure of the superior mesenteric artery, however, is followed with great regularity, probably constantly, by hemorrhagic infarction of the intestine."

#### REPORT OF CASES OF MESENTERIC VASCULAR OCCLUSION IN WHICH NO INTESTINAL CHANGES DEVELOPED

CASE 1—*History*—J. J., man, aged 80, white, admitted Jan. 4, 1909, had had an attack of shortness of breath one year previously. The second attack occurred two weeks before admission. Both of these attacks lasted only a few minutes. Otherwise the patient's past history was negative. Digestion had always been good and the bowels had moved regularly. There were no urologic symptoms before the present illness, and no history of gonorrhea or syphilis. For the last three years the patient had been growing gradually weaker. One week before admission, he began to have difficulty in voiding and during the week this difficulty increased. The patient had to be catheterized several times by his family physician.

<sup>7</sup> Loop R. G. Mesenteric Vascular Occlusion, J. A. M. A. **77** 359 (Jul 30) 1921.

<sup>8</sup> Welch W. H. in Allbutt System of Medicine **7**, 1899.

<sup>9</sup> Chiene I. Anat. & Physiol. **3** 65-107 1869.

*Physical Examination*—The patient was poorly nourished. Nothing abnormal was detected in the heart and lungs. The abdominal examination was entirely negative. Through the rectum a greatly enlarged prostate could be felt. The urine showed many pus cells.

*Course in Hospital*—The patient's condition became gradually worse, and on the seventeenth day in the hospital he died (January 21). Nothing abnormal was ever demonstrated in the patient's abdomen.

*Necropsy*—The anatomic diagnosis was "Prostatic enlargement, hemorrhagic cystitis, ureteritis and pyelonephritis, chronic fibrous myocarditis with thrombus formation, arteriosclerosis of the aorta with ulceration, mural thrombosis of the iliac artery, thrombosis with occlusion of the superior mesenteric artery, anastomotic circulation." The intestines remained normal because of the extensive anastomotic circulation, although the superior mesenteric artery was completely obstructed near its origin by a dense thrombotic mass.

*CASE 2—History*—G. I., man, aged 45, white, admitted May 13, 1915, gave an essentially negative history, with no mention of any dyspnea on exertion or swelling of the ankles. There had been no gastro-intestinal disturbances until the present illness. Six months before admission to the hospital, the patient began to complain of belching and constipation. During the last three months he had noticed that he was becoming more and more jaundiced and that his stools were white.

*Physical Examination*—The patient was very much emaciated and quite jaundiced. The temperature on admission was 99.6 F., the pulse, 100, respirations, 20. The liver could be felt three finger-breadths below the costal margin, but no abdominal tenderness was present. The patient's stools were clay-colored.

*Course in Hospital*—On the tenth day in the hospital the patient began for the first time to complain of abdominal pain and to vomit. His temperature rose to 104 F. An operation was immediately performed by Dr. McClure. A large amount of yellowish fluid was found in the peritoneum. There was a hole in the common duct. The gallbladder was drained, and several drains were placed in the peritoneal cavity. The patient died that evening.

*Necropsy*—The anatomic diagnosis was "Carcinoma of the head of the pancreas with metastases to the liver and neighboring lymph glands, obstruction of common duct, jaundice, thrombosis of the superior mesenteric artery. The intestines appeared normal, except for a few minute hemorrhages."

*CASE 3—History*—C. D., man, aged 51, colored, was admitted Oct. 3, 1919, with an entirely negative past history and with no history of any cardiovascular trouble. The present illness was limited to the condition for which the patient was operated on, double inguinal hernia. The patient had had the hernias for many years.

*Course in Hospital*—An operation was performed Oct. 14, 1919, for double hernia (Dr. Reid). At the tip of the large hernial sac on the right there was an abscess. Several loops of intestine were adherent to the abscess sac. A low right rectus incision was made and the abscess wall, with the loops of intestine still adherent, was sutured to the abdominal wall. Four days later the abscess was opened. The patient's temperature never returned to normal after the abscess had been opened and the course was gradually downward. November 17, the patient died.

*Necropsy*—The anatomic diagnosis was "Old inguinal hernia with strangulation and abscess formation, thrombosis of the inferior mesenteric vein, septic thrombosis of the main portal vein." The intestines were perfectly normal.



## COMMENT

Case 3 is the only instance in our series of thrombosis of the inferior mesenteric vessels. Other observers have also noted the relative infrequency of thrombosis of the inferior mesenteric vein as compared with its occurrence in the superior mesenteric vessels. Before leaving this case of associated portal and mesenteric thrombosis, it might be well to quote again from Welch's article "Of interest is the relation of thrombosis of the mesenteric veins to portal thrombosis. In several instances of the latter, thrombosis of the mesenteric veins occurred without hemorrhagic infarction of the intestine. Doubtless, the explanation is that a sufficient collateral circulation had been established after the portal thrombosis to prevent the usual effects of a subsequent mesenteric thrombosis. That this, however, is not always the case is shown by the sudden or more gradual termination in some instances of portal thrombosis with hemorrhagic infarction of the intestine in consequence of the extension of the thrombus into the mesenteric veins."

REPORT OF CASES OF MESENTERIC VASCULAR OCCLUSION  
CAUSING INTESTINAL INFARCTION WHICH WERE  
NOT TREATED SURGICALLY

CASE 4—*History*—H. H., man, aged 49, white, admitted, April 2, 1895, had been in the hospital three times previous to his last admission. A diagnosis of cirrhosis of the liver and diabetes mellitus was made on the first admission and was confirmed on all subsequent admissions. Four days before entering the hospital for the last time, the patient developed severe pain in the lower abdomen. The abdominal pain persisted during these four days, but at no time was there any vomiting.

*Physical Examination*—The patient looked very ill. The temperature was 100 F, the pulse, 110, and respirations, 20. The abdomen was markedly distended and general abdominal tenderness was present. The urine showed 25 per cent sugar.

*Course in Hospital*—The patient's course was rapidly downward, and he died on the second day, April 4. Just before death his temperature rose to 102 F.

*Autopsy*—The anatomic diagnosis was "Diabetes mellitus, cirrhosis of the liver, thrombosis of the portal and superior mesenteric veins, hemorrhagic infarction of the intestine."

*Comment*—This case is probably an example of (to quote again from Dr. Welch) "sudden or more gradual termination of portal thrombosis with hemorrhagic infarction of the intestine in consequence of the extension of the thrombus into the mesenteric veins." This patient had abdominal tenderness and distention, but as he was known to have diabetes mellitus and cirrhosis of the liver, the abdominal signs were attributed to those conditions. An acute condition of the abdomen demanding surgical intervention was not suspected and an operation was not considered.

CASE 5—*History*—D. B., man, aged 52, colored, admitted, Oct. 13, 1898, had been admitted to the hospital on four previous occasions. The diagnosis

on all these was aortic insufficiency, arteriosclerosis and mitral stenosis. On each admission, the patient's heart was found decompensated, but following rest and therapy, he was able to go back to work.

*Present Illness*—The patient was readmitted to the hospital, Oct 13, 1898, for another cardiac breakdown. On admission he had no abdominal symptoms and the abdomen was negative on examination. Six days after admission, the patient suddenly began to complain of pain in the lower abdomen, and the abdomen became almost instantly rigid and immobile. The temperature rose to 101 F, the pulse to 110. The patient died the following day, October 30. There was no vomiting at any time.

*Necropsy*—The anatomic diagnosis was "Arteriosclerosis, sclerosis of the aortic valve, thrombosis of the left ventricle, thrombosis of the superior mesenteric artery, hemorrhagic infarction of the intestine, acute peritonitis."

As the abdominal findings were rather characteristic of those found in cases of thrombosis of the main branch of the superior mesenteric artery with infarction of all the intestine supplied by that vessel, I shall quote in some detail the description of Dr. Simon Flexner who performed the necropsy.

"The peritoneal cavity contains several hundred cubic centimeters of thin sanguineopurulent fluid. The loops of intestine are much distended. They present a deep purplish color. The loops which are especially distended and hemorrhagic are those of the small intestine, the upper part of the large intestine is also involved. The superior mesenteric artery is thickened, its intima contains sclerotic and fatty patches, but there are no ulcers. Its lumen is completely filled with a moderately firm red thrombus, which is lightly adherent to the vessel walls. The length of the thrombus is about 3 cm. On closer inspection it is proved that the infarcted area extends so as to involve the duodenum, the jejunum and ileum throughout their entire lengths and the cecum and ascending portions of the colon. The transverse colon is involved in a part of its extent only. The content of the intestine is a fluid of serosanguineous composition. The mucous membrane of the small intestine is deeply suffused with blood, also that of the cecum and ascending colon."

While the presence of an acute abdominal condition was recognized in this case, an operation was not considered, as the patient's heart at the onset of the intestinal symptoms was markedly decompensated.

*CASE 6—History*—B. S., woman, aged 60, white, admitted, March 24, 1919, gave an entirely negative past history. The patient had always had good health until the onset of the present illness. Three weeks before admission, the patient developed shortness of breath and edema of the ankles. At the same time the abdomen began to swell, but there was no abdominal pain or vomiting at that time.

*Physical Examination*—The patient was somewhat cyanotic. The temperature was 97 F, the pulse, 110, respiration, 24, leukocyte count, 6,000. The pulse showed that the auricle was fibrillating. The abdomen was moderately distended and filled with fluid but was not tender. A diagnosis of cirrhosis of the liver, myocardial insufficiency and auricular fibrillation was made.

*Course in Hospital*—On the fifth day after admission, the patient developed severe abdominal pain and died on the following day, March 30. She vomited several times during the last two days. The leukocyte count rose from 6,000 to 24,000, but the temperature remained subnormal throughout.

*Necropsy*—The anatomic diagnosis was "General arteriosclerosis, fibrous myocarditis, cirrhosis of the liver, thrombosis of the superior mesenteric veins."

hemorrhagic infarction of the jejunum with hemorrhage into the stomach, duodenum, jejunum and ileum"

#### COMMENT

While it is true that at necropsy we might possibly say that surgical interference was indicated in these cases, still it was not possible during life to say more than that these patients had an acute abdominal condition. The cases of mesenteric vascular occlusion that are diagnosed as such are as rare as are the patients that recover from that condition. Moreover, two of these patients had decompensated hearts when the abdominal symptoms commenced, and the third had diabetes mellitus and cirrhosis of the liver, so the hope that laparotomy offered to these patients was almost negligible.

#### REPORT OF CASES OF MESENTERIC VASCULAR OCCLUSION TREATED SURGICALLY

**CASE 7—History**—C. C., man, aged 52 years, white, admitted, Sept 15, 1898, with an essentially negative past history, for three weeks had had some pain in the abdomen and occasional attacks of vomiting. Five days before admission to the hospital, the abdominal pain had become more severe and the vomiting had occurred more frequently.

**Physical Examination**—The temperature was 100 F, pulse, 72, respirations, 24. The patient appeared quite ill. The abdomen was moderately distended and definite muscle spasm was present.

**Operation** (Dr. Bloodgood)—"On opening the peritoneal cavity it was seen to contain a considerable amount of bloody fluid with no fecal odor. There was a mass present, which consisted of several coils of small intestine. The intestine appeared somewhat gangrenous and was quite dark in color. The mesentery below the intestine was also definitely engorged and blackened and the vessels of the mesentery seemed thrombosed. The gangrenous intestine was brought out of the abdomen but not resected. An enterostomy was done." The patient died on the second day after the operation, September 18.

**Necropsy**—The anatomic diagnosis was "Thrombosis of the mesenteric veins, necrosis and gangrene of the small intestine, general fibrinopurulent peritonitis." The mesenteric artery was free. The heart and aorta were normal.

**CASE 8—History**—G. W., woman, aged 45, white, was so ill when admitted to the hospital, July 14, 1900, that no past history could be obtained. Severe abdominal pain had started five days before admission. The pain had been especially severe a little to the left of the umbilicus. Vomiting had occurred frequently.

**Physical Examination**—The temperature was 100.2 F, the pulse, 140, respirations, 28, leukocyte count, 20,000. The history says, "Patient looks very ill. Abdomen is markedly distended and very tender on palpation. Considerable muscle spasm is present."

**Operation** (Dr. Mitchell)—"On opening the peritoneal cavity it was found to contain a great quantity of thin dark-brown fluid. A loop of distended blue-black small intestine was seen running transversely above the umbilicus and down the right side of the abdomen. There was a definite thrombus in the branch of the superior mesenteric artery supplying the discolored intestine. The gangrenous intestine was excised, some good intestine being removed at either

end in an attempt to take care of any extension of the thrombosis. The two ends of the intestine were brought out through the abdominal incision." The patient died on the following day, July 20. Permission for a necropsy could not be obtained.

*CASE 9—History*—J. S., man, aged 48, colored, admitted June 10, 1906, with an essentially negative past history, was admitted, June 9, 1906, on the medical service because of a severe cold he had had for two weeks. During the first day on the medical service, he vomited once. The next day vomiting occurred frequently and severe abdominal pain began. The temperature rose to 103 F and the leukocyte count to 13,000. The patient was at once transferred to the surgical service.

*Physical Examination*—When admitted on the surgical service, the patient was irrational. The abdomen was considerably distended and shifting dullness could be demonstrated in the flanks.

*Operation* (Dr. Sowers)—"On opening the peritoneal cavity, a small amount of turbid fluid with a foul odor poured out. Numerous loops of gangrenous intestine were seen. These loops were distended and quite black. Fifty-two inches of intestine was removed and the divided ends of the intestine brought out through the wound." The patient lived only a few hours after the operation.

*Necropsy*—The anatomic diagnosis was "General arteriosclerosis, thrombosis of the superior mesenteric artery, hemorrhagic infarction of the small intestine, acute fibrinous peritonitis, embolism of the pulmonary artery, hemorrhagic infarction of the lungs."

*CASE 10—History*—L. W., woman, aged 45, white, admitted, March 15, 1913, was on the medical service for some time before being transferred to the surgical service. The diagnosis on the medical service was Raynaud's disease, thrombosis of the left iliac vein and phlebitis of the left leg. Ten days before admission to the surgical service, pain in the lower abdomen began and continued up to the time of operation. Vomiting began on the day before operation. On the day of operation, the temperature rose to 100 F, the pulse to 110. The leukocyte count was 31,000.

*Physical Examination*—There was marked general abdominal tenderness, and some muscle spasm on both sides.

*Operation* (Dr. Finney)—"On opening the peritoneal cavity a mass was found in the upper abdomen. This mass proved to be several loops of intestine which were matted to each other and which were near the point of gangrene. The operator felt certain he had done nothing to relieve a volvulus and considered the condition to be one of mesenteric thrombosis. Thirty inches of intestine was removed and a lateral anastomosis done." The wound broke down after the operation and healed by granulation. On the eightieth day, June 3, the patient was discharged in fairly good general condition and with the abdominal incision entirely healed. On discharge the patient was having no abdominal symptoms and the signs of femoral thrombosis had almost entirely disappeared.

*CASE 11—History*—A. S., man, aged 38, white, admitted Oct. 15, 1913, with an entirely negative past history, for three days before entering the hospital had had severe pains in the abdomen. One day before admission, vomiting had begun and this had continued up to the time of operation.

*Physical Examination*—The patient did not look very ill. He could walk around and take off his clothes without difficulty. The temperature was 98.6 F,

the pulse, 80, respirations, 20, and leukocyte count, 9,000. The abdomen was markedly distended. There was moderate general abdominal tenderness and slight rigidity of the abdominal muscles.

*Operation* (Dr Heuer) —“On opening the peritoneal cavity there was an escape of several ounces of bloody fluid. The intestines were greatly distended. About a foot above the cecum the ileum passed from normal to greatly thickened friable intestine. The mesentery supplying the involved intestine was several times its normal thickness. The thickened bowel was resected, a considerable amount of normal intestine being removed from either end and a lateral anastomosis done.” The patient died a few hours after the operation, October 16. Permission for a necropsy was refused. The surgical pathologists reported that the resected intestine showed mesenteric thrombosis with necrosis of the intestinal mucosa.

*CASE 12—History*—J. K., woman, aged 42, white, admitted to the hospital, Jan. 26, 1918, gave an essentially negative past history with no mention of any heart trouble. The present illness began with sudden severe pain in the epigastrium on the morning of the day on which the patient was admitted to the hospital. The pain quickly spread over the entire abdomen. There was some nausea but no vomiting. The patient's family physician gave her a cathartic and an hour later an enema, but these measures were insufficient to cause the bowels to move.

*Physical Examination*—As the gynecologic extern, I saw this patient four hours after the onset of the symptoms and made the following note: “The patient is a young woman, lying in bed, complaining of considerable pain. She looks very ill, although her temperature by mouth is only 98 F, and her pulse, 90. The abdomen is normal in outline but moves only slightly with respiration. On palpation, moderate tenderness can be elicited over a central area extending about 6 cm. in all directions from the umbilicus. Over this area there is resistance but no true muscle spasm. There is no tenderness in the flanks and no dullness of the percussion note can be demonstrated. Pelvic and rectal examinations are negative.” The patient was admitted to the hospital with the idea that she probably had a beginning intestinal obstruction. During the patient's first four hours in the hospital the abdomen became distended and extremely tender. Generalized abdominal rigidity developed. The white blood count in these four hours rose from 10,000 to 36,000, and the pulse rate from 80 to 150 to the minute. Eight hours after the onset of the patient's first symptom, a laparotomy was performed.

*Operation* (Dr Wynne) —“On opening the peritoneal cavity a loop of distended small intestine was seen in the pelvis. This loop was quite black in color and the mesentery supplying it was also hemorrhagic. At either end there was a very definite line of demarcation between the normal and the infarcted intestine. The dark, distended intestine was resected and the two ends of the gut brought out through the upper angle of the midline incision. Drains were placed in both flanks through short McBurney incisions.” Following the operation the patient's condition remained critical for several weeks. Most of the food eaten escaped from the cut end of the upper loop of intestine, only slightly digested, so it was evident that the infarcted intestine must have been high up in the gastro-intestinal tract.

In addition to feeding the patient by mouth, we fed her peptonized milk and glucose through the lower loop of intestine. From that time on her condition gradually improved. Two unsuccessful attempts were made to close the

fecal fistula, extraperitoneally. On both occasions, end-to-end anastomoses were performed. Finally, July 10, 1918, a wide elliptic incision was made around the two enterostomy openings, an area of skin with some underlying fascia removed, the two ends of the intestine were brought out of the peritoneal cavity and resected, and a lateral anastomosis performed. This operation was performed by Dr. E. H. Richardson, as Dr. Wynne had then left the hospital for service in the Army. The patient was discharged six months after her first operation. The gynecologic pathologist, after examining the resected intestine with its attached mesentery, sustained the clinical diagnosis of intestinal infarction due to thrombosis of the mesenteric vessels.

**CASE 13—History**—B. C., woman, aged 31, white, admitted to the hospital, Feb. 8, 1921, gave an essentially negative past history with no mention of any cardiac trouble, and no history of any acute infection. Nine days before admission to the hospital, the patient began to have severe pain across the lower portion of the back and vomited once or twice on the day of onset of this pain. After eight days the backache suddenly disappeared and severe pain in the epigastrium commenced. That evening the vomiting recurred and the patient became delirious. On the following day, the day of admission to the hospital, the vomiting ceased, but the abdominal pain became generalized.

**Physical Examination**—The patient complained of severe abdominal pain. The leukocyte count was 45,000, the red blood count, 7,680,000, hemoglobin, 112 per cent. The abdomen was moderately distended. Generalized abdominal tenderness was present and muscle spasm could be demonstrated over the whole abdomen.

**Operation (Dr. Wharton)**—"On opening the peritoneum, a considerable amount of slightly blood-tinged fluid poured out. A coil of small intestine lay transversely across the midline incision. This coil of intestine was moderately distended and quite black in color. There was no evidence of any obstruction. There was no pulsation in the vessels of the mesentery going to the discolored intestines and this portion of the mesentery had itself the same dark color. The operator did a resection of the infarcted intestine, removing in all 60 inches of intestine and then did a lateral anastomosis."

The patient stood the operation fairly well, but, after returning to the ward, her condition became progressively worse and the following day she died, February 9.

**Necropsy**—The anatomic diagnosis was "Polycythemia, atrophy of the liver, thrombosis of the branches of the portal veins in the liver with extension to the portal trunk and branches supplying the stomach, intestine, pancreas and spleen, hypoplasia of the bone marrow, infarction of the small intestine, acute peritonitis." It was the impression of Dr. Putnam, who performed this necropsy, that the thrombosis started in one of the branches of the portal vein inside the liver and extended downward to the branches of the portal vein supplying the ileum, duodenum, jejunum and cecum.

Case 14, my own case, was the one that aroused my interest in this subject and for that reason I am reporting it in considerable detail.

**CASE 14—History**—M. P., woman, aged 24, white, admitted Sept. 10, 1921, had had one attack of acute rheumatic fever two years previously and slight edema of the ankles at times during the last six months. Otherwise her history was essentially negative. The patient had had a miscarriage ten days before admission to the hospital followed by an entirely afebrile and uneventful puerperium. The evening before admission while hanging,

clothes on the line, the patient felt "something give way inside of her" At once abdominal pain and vomiting began Dr McCormick, of Sparrows Point, Maryland, saw the patient that evening and advised her to come into the hospital, but she refused While the patient when first seen by Dr McCormick looked quite ill, her temperature was still normal During that evening and the next day the abdominal pain persisted and the vomiting occurred more frequently The patient entered the hospital thirty hours after the onset of symptoms

*Physical Examination*—The patient was an undernourished young woman, apparently very ill She was quite irrational The temperature was 102 F, the pulse rate, 120, and respirations, 30 The leukocyte count was 23,000 Examination of the lungs was negative Examination of the heart gave a positive diagnosis of mitral stenosis and insufficiency, with probably beginning aortic insufficiency The abdomen showed boardlike rigidity and generalized tenderness The pelvis appeared normal I recognized the fact that there was an acute condition of the abdomen, demanding operative interference In considering the causes of the acute abdominal condition, volvulus and mesenteric thrombosis were mentioned, but no exact diagnosis was made

*Operation* (Dr Brady)—On opening the peritoneum a moderately distended, boggy, purplish black loop of small intestine appeared in the incision (Fig 1) There was a small amount of serosanguineous fluid in the peritoneal cavity All the loops of small intestine appeared somewhat distended, but only 16 inches (40.6 cm) was dark purple The mesentery supplying the dark intestine was the same purple color all the way down to its root The line of demarcation between normal and infarcted intestine was very sharp at either end I saw no volvulus and I feel sure I did not release any twist of the mesentery in delivering the intestine, as this part of the operation was performed quite slowly to avoid tearing the gangrenous intestine All of the purple intestine, with an inch or two (2 or 5 cm) of normal intestine at either end, was then removed In doing this I took out as much as possible of the black mesentery The two ends of intestine were temporarily closed and then brought out through a right McBurney incision, and three drains were placed in the lower angle of the midline incision to take care of the peritonitis which was already present It was my impression at operation that the involved intestine was quite high up in the gastro-intestinal tract, although I did not stop to confirm my impression The day after the operation I opened both ends of the intestine that were coming out through the McBurney incision I did not know which end led to the stomach and which to the large intestine

*Course*—For three days the patient was in a critical condition, vomiting frequently and running a rapid pulse On the fourth day fecal material began to come out through one of the enterostomy openings for the first time and from then on the patient's condition steadily improved However, it was at once apparent that the material coming from the loop of intestine leading to the stomach was slightly digested food rather than fecal material Charcoal given by mouth always appeared in an hour and on one occasion, when the patient was apparently having diarrhea, charcoal appeared at the enterostomy opening fifteen minutes after being swallowed On the fifth day, therefore, we began feeding the patient glucose and peptonized milk through the lower loop, as well as giving her everything she wished by mouth

The patient's general condition steadily improved, but in spite of frequent dressings and the use of every known protective around the enterostomy opera-



Fig. 1. The purplish black of the intestine and of the mesentery extended to the root, as shown, *a*, sharp line of demarcation between the inverted and normal intestine.





ings, it was evident that the secretions from the upper loop were beginning to digest away the skin. On the twentieth day we took all the dressings off the patient and put her in a continuous bath. We were able to do this, for by this time the midline incision had healed perfectly. Two days in the continuous bath improved the skin condition considerably, but we were afraid to continue this treatment as it was difficult to keep the water at exactly the right temperature. If the temperature of the water was a few degrees above body heat, the patient complained of weakness, whereas the slightest drop in temperature caused her to become cyanotic. October 3, twenty-three days after the first operation, a wide elliptic incision was made around the enterostomy openings, the skin with the adherent intestinal loops were brought out of the abdomen, the afferent and efferent cords divided about 2 inches (5 cm) below the point where they came to the surface and a lateral anastomosis was performed. The patient recovered quickly from the second operation and was discharged two months after her first operation in very good general condition and with the two incisions well healed.

*Comment*—Microscopic sections of the intestine removed at operation showed necrosis of the intestinal wall. Sections of the mesenteric vessels showed the lumen of the veins filled with antemortem blood clots and an accumulation of pus cells along the vessel walls. The arteries appeared normal. Figure 1 is a reproduction of a water color of the infarcted intestine as it appeared at operation. Figures 2 and 3 are low and high power photomicrographs of the mesentery. They show occlusion of the veins and the accumulation of leukocytes along the vein walls.

#### SUMMARY

1 Eleven of the fourteen cases of mesenteric vascular occlusion that have occurred in the Johns Hopkins Hospital produced intestinal infarction. In three instances, the thromboses progressed very slowly and sufficient collateral circulation developed to prevent the formation of an infarction. These three cases were, of course recognized only at necropsy, as the patient had no symptoms referable to the thrombosis.

2 In thirteen of our cases, the superior mesenteric vessels were involved, in one instance the inferior.

3 The mesenteric arteries were involved in four cases, the veins in eight. In two cases it was impossible to tell which of the two caused the infarction. These findings are at variance with those of most observers, for in the majority of articles on this subject the veins are said to be involved much less frequently than the arteries.

4 When the mesenteric veins are occluded, it is always due to thrombosis. Either embolism or thrombosis may cause occlusion of the mesenteric arteries. In our series the four instances of occlusion of the mesenteric arteries are all recorded as being due to thrombosis. However at necropsy it is frequently difficult to differentiate between thrombosis and embolism of the mesenteric arteries.

5 The average age of the patients in our series was 45 years. The oldest patient was 80 the youngest 24.

6 Eight of our patients were men, six women. Eleven were white, three were colored.

7 As causes of venous thrombosis all factors causing stasis of the portal system are of importance. Endocarditis, arteriosclerosis and any

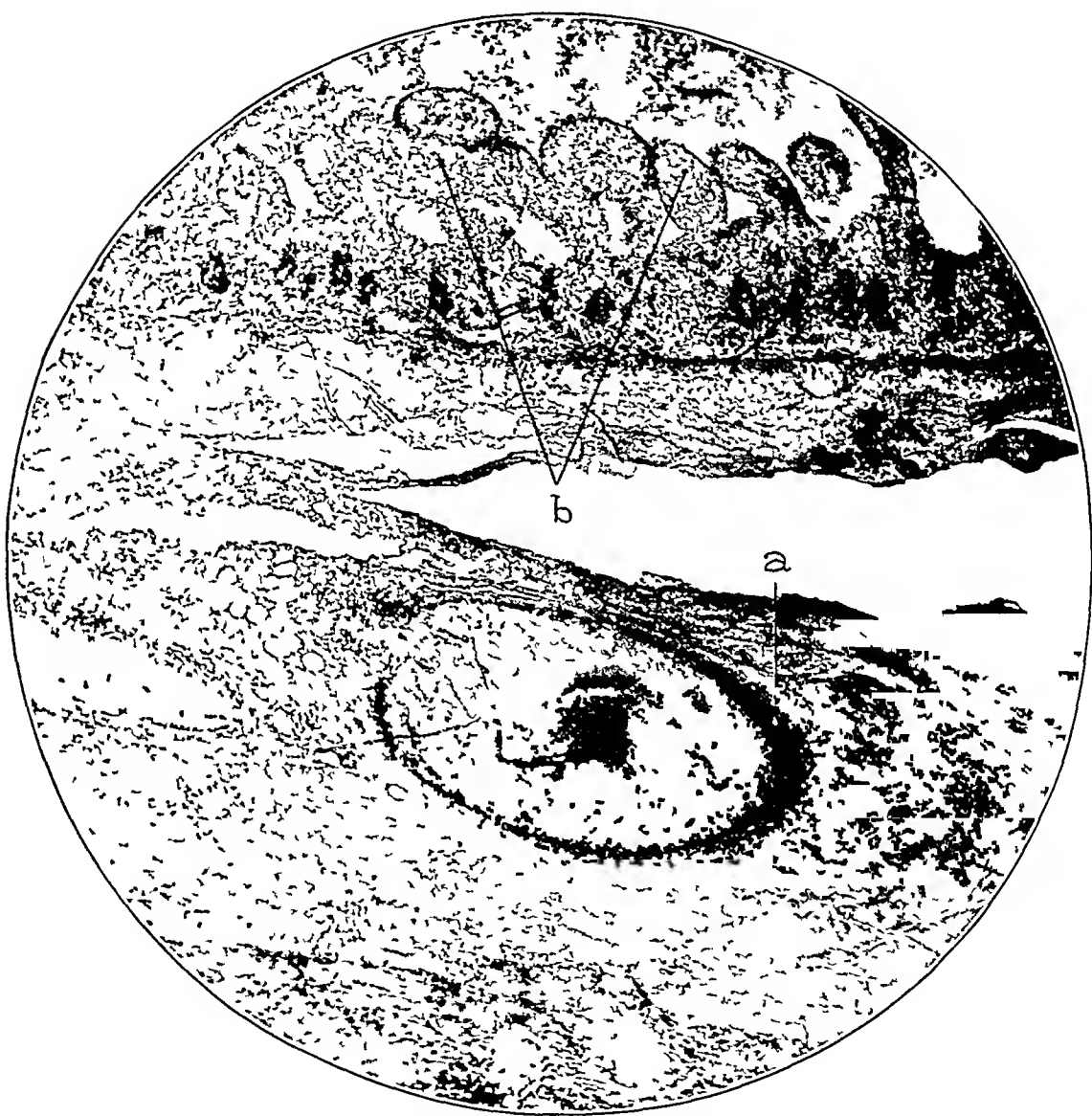


FIG. 2—Low power photomicrograph of mesentery (a) the accumulation of leukocytes along the thrombosed vein, (b) the necrotic intestinal villi.

condition leading to the formation of thrombi may be responsible for the mesenteric vascular occlusion. In ten of our cases, the following etiologic factors were found: in four we could find absolutely no cause for the occurrence of the thrombosis; endocarditis with aortic insufficiency; marked stenosis clinically; two patients marked arteriosclerosis; two

patients, cirrhosis of the liver, 2 patients, Raynaud's disease, 1 patient, carcinoma of the pancreas with metastases to the liver and neighboring glands, 1 patient, polycythemia, 1 patient, and partially strangulated inguinal hernia with abscess formation, 1 patient

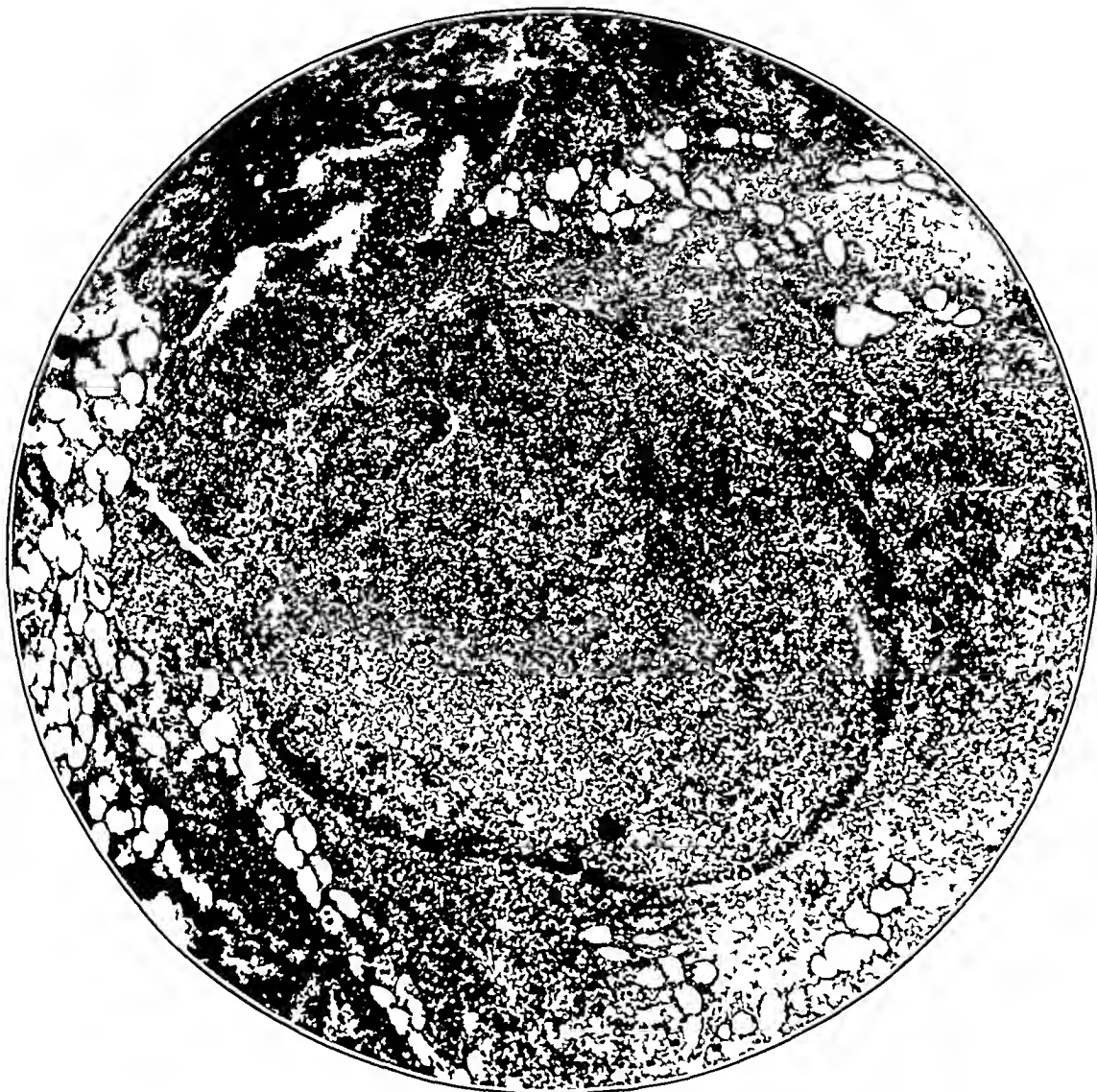


Fig 3—High power photomicrograph of the thrombosed vein shown in Figure 2

8 In all of our cases there has been a history of abdominal pain and vomiting, and on examination abdominal tenderness and muscle spasm were demonstrated. At the onset of the thrombosis there was little elevation of temperature, but at the end of twenty-four hours almost every patient had a temperature of at least 102 F. The leuko-

cyte count and the pulse rate usually rose before the temperature. In most cases the white blood count was 20,000 and the pulse rate at least 120 to the minute, even when the patient was seen within the first twelve hours after the onset of symptoms. Constipation was present in all of our patients, but in only two instances was there any passage of blood by rectum. The majority of our patients, even from the first, were greatly prostrated and looked ill.

9 In the majority of our cases of mesenteric vascular occlusion the progress of the condition was rapidly downward, with steadily increasing abdominal pain and with rising temperature and leukocyte count. For instance, one patient (Case 5) had abdominal symptoms for less than twenty-four hours before death, still at necropsy the entire small intestine was infarcted. Of course, the rapidity with which symptoms develop varies according to the size of the branch of the mesenteric vessel which is occluded, but in our series rapid progress downward has been the rule. Another patient (Case 7) affords the one exception to this rule. He had abdominal pain and vomiting for three weeks, and at necropsy only 3 feet (91.5 cm.) of small intestine was found to be infarcted. The accompanying table gives the duration of symptoms in our eleven cases of intestinal infarction.

DURATION OF SYMPTOMS IN ELEVEN CASES OF INTESTINAL INFARCTION

Number of Patients	Duration of Symptoms Before Operation or Death	Number of Patients	Duration of Symptoms Before Operation or Death
	Days		Days
3	1	1	5
2	2	1	9
2	3	1	23
1	4		

10 Although some writers on this subject apparently believe there is a clinical picture which is diagnostic of mesenteric vascular occlusion, I have been compelled from a study of our cases, to agree with those that maintain that the picture is indistinguishable from that of acute intestinal obstruction due to causes other than mesenteric thrombosis. In a patient with cirrhosis of the liver or endocarditis suddenly develops an acute abdominal condition, one may suspect a mesenteric thrombosis, but the instances in which one can say that "the patient has a mesenteric thrombosis and not a volvulus or strangulated hernia" will probably always remain rare.

11 When the abdomen is opened in a case of mesenteric thrombosis the peritoneal cavity is usually found to contain a moderate

amount of serosanguineous fluid. In advanced cases this fluid is frequently sanguineopurulent. The infarcted intestine is moderately distended and purplish black. The line of demarcation between normal and infarcted intestine is usually, but not always, sharp. The walls of the involved intestine feel soggy, and the intestinal lumen contains a considerable amount of fluid. The mesentery supplying the infarcted intestine is the same purplish black as the intestine, down to the root. Just how much inflammatory reaction the intestine not supplied by the thrombosed vessel shows depends on how far the secondary peritonitis has developed.

12 In intestinal infarction there is just one method of treatment—immediate laparotomy. Some surgeons believe that when the patient's general condition is sufficiently good to warrant prolonging the anesthesia for the necessary length of time, the proper operation is a resection of the intestine and a lateral anastomosis, whereas others believe that the anastomosis should never be performed at the primary operation. I agree with the latter view for these reasons. Patients with intestinal infarction are usually seriously ill, and an extensive intestinal resection with an anastomosis requires so much time and involves so much handling of the parts that the patients's endurance is likely to be overtaxed. Moreover, after the anastomosis has been completed, the vascular lesion with resulting infarction of the intestine may progress and cause the failure of an otherwise satisfactory operation. To quote from Moynihan<sup>10</sup> "The safest measure to adopt in all cases is the resection of the bowel which is undoubtedly involved and the establishment of an artificial anus."

13 In very desperate cases and in cases in which a great many feet of intestine is found at operation to be gangrenous, the procedure advocated by Mikulicz may be carried out, that is, to bring all the gangrenous intestine out of the abdomen, to fix it parallel to the wound and to perform enterostomy, at a latter stage dealing with the gangrenous intestine. In this connection one of Dr. Thomas S. Cullen's cases is instructive.<sup>11</sup>

His patient had been operated on for a very large multilocular cystadenoma of the ovary. Six weeks later, while at her home apparently recovered from the first operation, she stooped over in her garden to pick something off the ground. She suddenly felt, as she expressed it, that something was wrong in her abdomen.

Dr. Cullen saw her on the second day with her physician, Dr. J. C. Gilland, of Greencastle, Pa. She was transported 130 miles (208 km.)

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<sup>10</sup> Moynihan, G. A. *Abdominal Operations*. Philadelphia: W. B. Saunders Company, 2, 1906.

<sup>11</sup> Personal communication.

and the abdomen opened at the Church Home and Infirmary on the following day, three days after the onset of the trouble. On opening the abdomen Dr. Cullen found all but 2 feet (61 cm) of the small bowel, brown and leathery. He at once recognized mesenteric thrombosis. Nothing could be done, so he merely placed two small cigaret drains in the abdomen and closed the incision. The patient lived for ten days after operation—in all thirteen days after the onset of the trouble.

14. In my own case the following procedure gave very satisfactory results. The infarcted intestine with about 2 inches (5 cm) of good intestine at either end is resected through a lower abdominal midline incision. The two ends of the intestine are temporarily closed and brought out through a short McBurney incision. If drainage of the peritoneal cavity is indicated (and it is nearly always indicated in cases of intestinal infarction), it is carried out through the lower angle of the midline incision or through a McBurney incision on the side opposite that on which the enterostomy opening is to be. The McBurney incision should be made as far laterally as possible, so as to diminish the chances of infecting the midline incision. The advantages of having the enterostomy openings in a short McBurney rather than in a low midline incision are obvious. The midline incision does not so readily become infected and the closure of the enterostomy at the second operation is much simpler. The intestinal loops may be opened with safety a few hours after the operation, in fact, if the patient's condition is desperate, they may be opened sooner. It seems to be a good procedure to open not only the loop leading to the stomach but also the one leading to the rectum, for in the two cases I have seen treated in this way, there was a great deal of discharge from the lower loop for several days after the operation. Apparently, by antiperistaltic action, the normal intestine gets rid of the toxins which have undoubtedly poured into it from the infarcted intestine. Moreover when the lesion is near the stomach, as it happened to be in these two cases, in addition to feeding the patient by mouth, water, peptonized milk and glucose should be introduced into the lower loop.

At the second operation, an incision is made around the enterostomes. The two ends of intestine with perhaps 1 cm of surrounding skin, mesentery and peritoneum are brought out of the peritoneal cavity in one block and a resection and lateral anastomosis are performed. By first entering the peritoneal cavity several centimeters above the enterostomes and introducing a finger into the abdomen, one can perform the block dissection of the abdominal wall without fear of injuring the intestines. The use of the continuous bath for several days before the second operation will often improve markedly the condition of the

patient's skin, but one must use great care in keeping the water at exactly the correct temperature

15 Since the mesenteric vascular occlusion in three of our fourteen cases played no part in causing the patient's death, I feel justified in omitting those cases when calculating the mortality. Eight of the eleven cases of mesenteric vascular occlusion that caused intestinal infarction proved fatal—giving a mortality of 72.5 per cent. Five of our eight patients treated by laparotomy died—an operative mortality of 62.5 per cent. These seem to be high figures, but when one learns that in 1904, Jackson, Porter and Quinby reported a total mortality of 94 per cent and an operative mortality of 92 per cent for all the cases known to have occurred up to that time, one realizes how peculiarly fortunate we have been in this clinic.

16 The hope of saving the lives of more patients with mesenteric vascular occlusion lies in recognizing promptly not necessarily that these patients have a mesenteric thrombosis, but that they have an acute abdominal condition demanding surgical interference.



# BILATERAL CHRONIC OPEN PNEUMOTHORAX CURED BY NEGATIVE TENSION

## REPORT OF CASE ~

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MONTREAL, CANADA

The use of negative tension in cases of subacute and chronic empyema, in which pronounced thickening of the visceral pleura is absent, has a very definite field of usefulness, as is illustrated by the case here described

## REPORT OF CASE

*History*—A man, aged 21, a resident of Troy, Vermont, was admitted to the Montreal General Hospital, May 18, 1920, with the history, given by his physician Dr Adams, that the patient had developed influenza, complicated by pneumonia Jan 29, 1920. February 25, at the patient's home, an intercostal thoracotomy was performed for the drainage of a right-sided empyema. Later he was removed to a hospital in Massachusetts, and, March 23, a left-sided empyema was relieved by intercostal drainage. Both wounds continued to discharge foul-smelling pus. The temperature ranged between 99 and 101 F, with occasional exacerbations, accompanied by chills. The patient lost ground steadily. There was progressive emaciation and the development of pronounced anemia.

May 17, approximately three months from the date of drainage of the right-sided empyema, the relatives of the patient decided to remove him from the hospital to his home, as no hope could be held out for his recovery. While en route to Vermont, it was decided to bring the patient to Montreal. He was admitted to the Montreal General Hospital, May 18, in a critical condition.

*Examination*—The emaciation was the most extreme that I have ever witnessed. There was urgent air hunger, all of the accessory muscles of respiration being brought into play. With each inspiratory act, the mandible was depressed and the tongue pushed forward. The face was cyanosed. There were audible rhonchi. Thoracic movements were limited to the left upper half of the chest.

*Course*—Shortly after admission a serious collapse occurred and death was thought to be imminent. The patient, however, responded to hypodermic injections of camphor and atropin.

As soon as this condition permitted a roentgenogram was taken and the thoracotomy wounds inspected. Through that on the right side, which was 2 cm in diameter and situated in the sixth intercostal space in the midscapular line, could be seen at each inspiration the movement of the collapsed right lung toward the opposite side. From this wound there was a moderate amount of air and charge.



Fig 1—Complete collapse of the right lung and partial collapse of the left lung. The lung shadow on the left side, immediately above the cavity, is denser than normal. The tube in the right pleural cavity was one which was lost six weeks before admission, and extracted through the old thoracotomy wound, shortly after the patient entered the hospital. As evidence of the extreme emaciation, the absence of soft tissue contours should be noted in Figures 1, 2 and 3.



Fig 2—Cavity on the right side and almost complete obliteration of the cavity on the left, with disappearance of the area of increased density in the latter location occupying the middle zone shown in Figure 1, reduced about one-third.



Fig 3—Cavity on the right side, with only a sinus remaining on the left side, reduced about two-thirds



Fig 4—Small residual cavity on the right, containing 5 cc of bismuth paste

On the left side a drainage tract was placed in the seventh intercostal space in the posterior axillary line, which was about 1 cm in diameter. The discharge was similar to that on the right side. There was a complete right-sided pneumothorax, while on the left only the lower lobe was collapsed. Any attempt to turn the patient toward the left side increased the dyspnea.

A negative tension apparatus was adjusted on the right side, with immediate lessening of the respiratory distress, giving play, as it did, to the uncollapsed portion of the left lung. Up to this point it would appear that the patient had been living on tidal air, with little or no vital capacity. On the following day, May 19, negative tension was induced in the cavity on the left side. During the ensuing fortnight this man passed through several respiratory crises, which were relieved by the administration of morphin and atropin.

Subsequently, there was rapid recovery of the appetite. The patient remained afebrile. The roentgenograms revealed progressive reexpansion of both lungs. August 2, approximately eleven weeks after admission, he was discharged with both cavities obliterated.

#### COMMENT

The extent of the emaciation may be gaged by the fact that, after the display of an exceptionally vigorous appetite for several weeks before leaving the hospital, the patient's weight, estimated on admission to be about 70 pounds (31.7 kg), on the day of discharge was only 104 pounds (47 kg). In October, two months after discharge, he weighed 134 (61 kg), and in December, 147 pounds (66.8 kg). In October he resumed work as a clerk in his father's store, and has since been in normal health. I think it is an undeniable fact that this patient would have died but for the employment of negative tension. The drainage apparatus employed in this case was similar to the apparatus that I<sup>1</sup> described in 1911.

219 Peel Street

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1 Eberts E M Ann Surg 54 58, 1911

# OUTLINE OF TREATMENT OF FRACTURES

SYLLABUS ADOPTED AT THE BOSTON CONFERENCE, APRIL, 1922

For a long time now, and especially since the armistice, there has been a strong desire among surgeons to simplify and standardize the treatment of fractures. The individual preferences were, before the war, so diverse that this seemed impossible, and since the war few have believed that any group of men could get together and agree on the essentials of the treatment of fractures. At a medical meeting held in January, 1922, it was suggested that an attempt be made by a group of men interested in fractures to come to some agreement as to the treatment of the more frequent ones. Those present suggested that the Massachusetts General Hospital call the meeting, as the first fracture service had been established there, in 1917, by Dr Charles L Scudder.

The suggestion was taken up and the men who have signed this syllabus gathered at the Massachusetts General Hospital in April, 1922 and agreed on the syllabus herewith appended, except in a few minor details which did not seem to be of vital importance.

The apparent unanimity of the group on all the essentials was so unexpected and seemed so important that it was determined to publish the syllabus as a guide for those who might desire some assistance. It can obviously carry only the weight of the experience of the surgeons attending the conference. In regard to certain details, there are naturally minor differences of opinion.

The following surgeons have agreed to the essentials of the syllabus: James M Hitzrot, William Darrach, Fordyce B St John and Seth M Milliken, New York, W Irving Clark, Jr, Worcester, Mass, Fred J Tees, Campbell B Keenan and Fraser B Gurd, Montreal, Canada, Fred A Coller, Ann Arbor, Mich, George W Hawley, Bridgeport, Conn, William S Baer, Baltimore, Astley P C Ashhurst and George M Dorrance, Philadelphia, Paul B Magnuson, Chicago, W O'Neill Sherman, Pittsburgh, Murray S Danforth, Providence, R I, Charles L Scudder, Fred J Cotton, Daniel F Jones, Robert B Osgood, Zabdiel B Adams, Henry C Marble, Torr W Harmer, Philip D Wilson, Arthur W Allen, and George A Leland, Jr, Boston.

## OUTLINE OF TREATMENT OF FRACTURES

### I First Aid

Every effort should be made to avoid any injury additional to that of the original trauma.

- 1 "Splint 'em where they lie"
- 2 Avoid every unnecessary manipulation
- 3 Transport with extreme care
- 4 Treat any existing shock

## II Examination

As complete and thorough an examination as possible should be made without causing any additional injury

- 1 Begin with painless procedures
- 2 Search for crepitus and abnormal mobility only when these symptoms are absolutely essential. The manipulation required to elicit these cause additional injuries
- 3 Rule out, if possible, other associated injuries, especially those of nerves
- 4 Elicit objective symptoms, which will be painful, only under an anesthetic
- 5 Roentgen-ray examination should be made as early as possible, roentgenograms should be taken in two planes, stereoscopic when necessary, should be of sufficient size, and should be studied with detailed care

## III Diagnosis

The simple diagnosis that a fracture exists is not sufficient. All details of pathology of the soft parts, as well as of the bone, should be considered, so as to visualize properly the problem of obtaining and maintaining reduction as well as the problem of repair and its probable duration.

## IV Treatment

Each fracture should be considered as an individual problem and the treatment directed not only to the injury of the bone but to that of the soft parts as well. The pathologic changes following a fracture interfere markedly with the ease of reduction of displaced fragments. These changes begin very soon after the injury. Infiltration of the adjacent soft parts, coagulation and later organization of the blood are the most important.

### 1 Obtaining Reduction

- (a) Reduction of any existing displacement should be made as soon after the injury as possible, without waiting too many hours for the roentgen-ray examination
- (b) Reduction should be as gentle as possible
- (c) Reduction should be as complete as the individual case requires
- (d) Reduction may be controlled by fluoroscopic examination in appropriate cases
- (e) Reduction should be checked by a roentgen-ray examination as soon as practical
- (f) Manipulation should be carried out under an anesthetic with but few exceptions
- (g) Further attempts at reduction should be made as soon as the need is recognized

### 2 Maintaining Reduction

- (a) Decide in each case the peculiar problem presented and select apparatus accordingly, both for immediate and subsequent use
- (b) A decision should be reached as to how early such apparatus can be temporarily discarded to allow for massage and motion and how long it should be worn in order to protect against further injury

- (c) Repair in cancellous is more rapid than in cortical bone
- (d) Rapidity of repair will depend very largely on the blood supply of the fragments
- (e) The atrophy of disuse must be borne in mind
- (f) The inherent value of any apparatus is of less importance than the skill with which it is used

### 3 Plaster of Paris

Circular plaster bandages are permissible only when completely divided in at least one line

### 4 Massage and Movements

If carefully and gently carried out, massage and movements can be of the greatest help. If roughly performed, they may do considerable harm. One must differentiate, under massage, between

- (a) Gentle stroking without deep pressure
- (b) Stroking with deep pressure
- (c) Kneading

One must differentiate between

- (a) Guided active motion
- (b) Unaided active motion
- (c) Passive motion

With these differences in mind, the various forms of each may be begun as soon as there is no danger of any additional injury or any displacement of the fragments resulting. This gentle massage and movements may cause discomfort but should never cause actual pain. The pain of forced passive movements usually means harmful stretching or tearing of soft parts, with additional necessary repair.

## V Operative Treatment

Operative treatment is indicated when a satisfactory reduction cannot be obtained and maintained by nonoperative methods, provided there is no contraindication, and when the expected result of the open method is sufficiently better than that of the closed to justify the additional risk.

Furthermore, it is generally recognized and accepted that, in certain types of fractures, it is impossible to obtain satisfactory restitution except by operative methods.

The operative method is recommended to those surgeons who have had special training and experience, who have the necessary skill and judgment, and who have the hospital facilities and surgical armamentarium with which to do this work properly. In the case of those who do not have such facilities, operation is not advised.

Internal splinting of long bones is usually best made by fixation with steel plates and screws, having a minimum of foreign material but with maximum strength and ductility. The machine type screw only should be used. The wood, or so-called carpenter, screws are contraindicated in the cortex of bones. A scrupulous nonhand contact technic should be carried out, with strict attention to detail. The

skin should be carefully covered during the operation, and there should be special care and preparation of the skin before operation. Intra-medullary fixation by bone graft or splints is contraindicated if any other method is possible.

Bone grafting is indicated chiefly in loss of substance and pseudo arthrosis. It is not indicated in the treatment of acute fractures. Every attempt to stimulate osteogenesis should be exerted before attempting to bone-graft for delayed union.

## VI Compound Fractures

In all compound fractures, patients are to receive tetanus antitoxin. Compound fractures in which it is perfectly evident that the wound of the soft parts is made by the protrusion of bone from within outward through the skin, and in which the wound is tiny, should have a thorough preparation of the skin by washing with benzoin, shaving (away from the wound), drying with ether and the application of tincture of iodine to the skin and the wound itself, with sterile dressing. Immediate reduction should be undertaken when indicated. When a roentgen-ray examination is to be made before reduction, all the steps enumerated above, except reduction, are to be completed before the patient is sent to the roentgen-ray department.

In extensive compound fractures with a large wound

1. Apply tourniquet only when it is obvious that some large vessel has been lacerated.
2. With a sterile sponge, carefully protect the wound from contamination while the skin is being cleansed, following the foregoing routine, in addition, chlorinated soda solution 1:40 may be found of value in removing grease. If this procedure can be undertaken without too much pain and shock to the patient, it should be carried out before he is sent to the roentgen-ray department, if not, apply tincture of iodine only to the edges of the wound, and put on a large sterile dressing before roentgen-ray examination, and complete the procedure when the patient is under anesthesia.
3. At operation debridement
  - (a) Thorough exposure of wound by generous incisions.
  - (b) Excision en bloc of traumatized and infected tissues.
  - (c) Excision of skin at least 0.5 cm. from the wound edges.
  - (d) Dead and dying fat, fascia and muscle cut away with sharp instruments until fresh bleeding occurs.
  - (e) Small bone fragments unattached to periosteum removed; soiled bone surfaces rongueured.
  - (f) Hematoma dissecting between muscle planes should be carefully evacuated.
  - (g) Frequent changes of gloves and instruments to insure against carrying infection into deep portions of wound.
  - (h) Irrigation of the wound with salt solution to wash out



SCHEMATIC TABULATION OF TREATMENT OF FRACTURES

Bone	Part of Bone	Reduction	Immobilization	Position	Secondary Splinting (Duration)	Convalescent Brace (Duration)	Physiotherapy (Time to Begin)	
							Massage	Active Motion
Clavicle	Outer, mid, inner thirds	Manipulation with or without anesthesia	Clavicular cross, no sling necessary	Shoulders back, up and out	1 Same, 3 to 5 weeks 2 Recumbency in dorsal decubitus with posterior pad, 10 days to 3 weeks	None Clavicular cross, 2 wks	None None	Immediate 3 wks
	1 Body 2 Neck	No manipulation Manipulation with or without anesthesia	Sling with or without adhesive Sling and axillary pad	Arm to side Arm to side	1 Same, 3 weeks 2 a Same, 3 weeks, b or without swathe, 1 to 2 weeks c Recumbency (for those displaced)	Sling, 1 to 2 wks Sling, 1 wk	1 wk 1 to 3 wks	2 to 4 wks 4 wks
Shoulder (Humerus)	1 Antionic neck 2 Sulclat neck a Impacted b Without marked displacement (as for a) c With marked displacement (as for d) d Incomplete (children) e Epiphysis	1 No manipulation b No manipulation c Manipulation with anatomic reposition with or without anesthesia d Manipulation with or without anesthesia e Careful manipulation with or without anesthesia No manipulation	Axillary pad (sweat pad only), circular bandage, circular sling or as per d (omit for e) Abduction and traction by Thomas arm or aeroplane splints or as for a Traction in Thomas arm splint Acroplane splint or plaster spica	1 Arm to side or abduction b Arm to side c Arm to side or abduction d Abduction or arm to side e Abduction	1 Same, 2 to 3 days b Same, 1 to 3 weeks c Same, 3 to 4 weeks d Same, 4 to 6 weeks Operation, plaster of Paris or aeroplane splint, 4 to 6 weeks 1 Same, 3 to 5 weeks 2 Operation if necessary Same, 4 to 8 weeks	1 Sling, 3 wks	3 days	3 d to 3 wks
	Unimpacted					b Sling, 2 to 3 wks c Sling, 2 to 3 wks d Sling, 1 to 2 wks	Not necessary Not necessary 3 d to 3 wks	1 to 3 wks 2 to 4 wks 2 to 4 wks
Humerus	1 Fracture dislocation 2 Greater tuberosity 3 Shift a Upper and mid thirds (above insertion of deltoid)	Manipulation with or without anesthesia	1 Hinged Thomas arm splint 2 Jones humerus splint with or without convection splints avoiding axillary pressure 3 Axillary pad circular and sling to wrist	Abduction and external rotation Arm to side	Operation, plaster of Paris or aeroplane splint, 4 to 6 weeks 1 Same, 3 to 5 weeks 2 Operation if necessary Same, 4 to 8 weeks	Sling, 2 to 4 wks Sling, 1 to 2 wks Corpectation splints and sling 2 to 4 wks	2 to 5 wks 1 to 5 wks 1 to 3 wks	2 to 5 wks 3 to 5 wks 4 to 8 wks (shoulder)

[illegible]

SCHLIMMATIC TABULATION OF TREATMENT OF FRACTURES—(Continued)

Bone	Part of Bone	Reduction	Immobilization	Position	Secondary Splinting (Duration)	Convalescent Brace (Duration)	Physiotherapy (Time to Begin)	
							Massage	Active Motion
Radius	b Displaced	Manipulation with or without anesthesia	b Same as humerus, 5, a		2 b Same as 1, b, 5 to 7 weeks	2 b Slng, 2 wks	1 wk	Flexion, pronation, supination, 2 to 3 wks
	1 Both bones	Manipulation with or without anesthesia	1 a Anterior and posterior wooden splints and anterior right inguinal splint or molded posterior plaster splint b Molded anterior and posterior plaster splints to include palm c Plaster collar to palm d Traction and suspension 2 Same as 1 a, b or c	1 Forearm supinated, elbow flexed at right angle  2 Upper third (above insertion of pronator teres), supination with elbow at right angle, below in position of pronator teres, pronation with elbow at right angle 3 Midpronation 4 Supination with elbow at right angle	Same, 5 to 7 weeks, children, 3 to 5 weeks  Same, 4 to 6 weeks  Same, 3 to 4 weeks Same, 3 to 5 weeks or 1, 2 and 3 a Traction, 3 to 6 weeks 1 Jones humerus splint 2 Overhead suspension, 4 to 6 weeks b Open reduction	Slng, 2 to 3 wks Slng, 3 to 6 wks  Slng, 2 to 3 wks Slng, 2 to 4 wks  Slng or plaster, 2 to 3 wks	1 to 4 wks  1 to 3 wks  1 to 3 wks Not necessary 3 to 6 wks	4 to 6 wks  2 to 4 wks 2 to 4 wks 3 to 6 wks
Radius	2 Radius (alone)	Manipulation with or without anesthesia	3 Same as 1 a, b or c 4 Same as 1 a, b or c					
	3 Ulna (alone) 4 Greenstick	Manipulation with or without anesthesia Manipulation with or without anesthesia	a Anterior and posterior wooden splints with cutout for ulnar styloid with fingers free b Plaster a Wooden splint b Plaster Same as for 1	1 a Hand adducted and pronated with palm at flexion b in bad displacements extreme of foregolfing position 2 Same as 1 3 Hand adducted and slight dorsal flexion	1 Same, 2 to 3 weeks  2 Same 2 to 3 weeks 3 Same 2 to 3 weeks	1 Wrist strap, 1 to 5 wks b Wrist strap 2 to 6 wks Wrist strap 2 to 6 wks Wrist strap 2 to 6 wks	2 days to 3 wks 2 to 7 days 2 days to 3 wks	1 to 3 wks 2 to 7 days 1 to 3 wks

Complications	Scapulothoracic joint	Manipulation	Molded plaster anterior cock up splint from elbow to finger tips	Dorsal flexion of hand in position of grasp	Same, 4 to 6 weeks or Reduction of displaced fragment by open reduction with cock up for 4 to 6 weeks	Wrist strip, 2 to 6 wks Wrist strip, 2 to 6 wks	1 to 3 wks 1 to 3 wks	4 to 6 wks 1 to 6 wks
Metacarpals	Metacarpals	Manipulation with anesthesia	Traction in small banjo splint	Hyperextension	Same, 3 weeks	None	1 to 3 wks	3 wks
	Metacarpals	No manipulation with anesthesia	Concave palmar splint	Position of grip	Same, 2 to 4 weeks	None	2 days	1 to 2 wks
	Metacarpals	Manipulation with anesthesia if necessary	Traction in small banjo splint with cock up to palm	Extension	Same, 3 to 5 weeks	None	1 wk	2 to 3 wks
Phalanges	Phalanges	No manipulation	Palmar splint for injured and adjacent fingers or traction	Partial flexion	Same, 2 weeks	None	Immediate to 1 wk	1 wk
	Phalanges	Manipulation with anesthesia	Traction in small banjo splint	Partial flexion	Same, 2 weeks	Palmar splint, 1 wk	1 wk	2 wks
	Phalanges	No manipulation	Adhesive strapping (two thirds circumference) with arms dependent	Full extension	10 days to 2 weeks	None	None	None
Radius	Radius	Reduction if possible with or without anesthesia	Swathe if necessary with suspension in Balkan frame or Sincelair net bed	Supine	Same, 4 to 12 weeks	Belt	None	5 to 8 wks
	Radius	No manipulation	Tight swathe not advised	Supine	Same, 4 to 12 weeks	None	None	5 to 8 wks
	Radius	Manipulation with anesthesia	Traction (Muller's) Plaster splint (in abduction)	Abduction	Same, 6 to 12 weeks	Cylinder	1 wk	6 to 12 wks
Ulna	Ulna	Manipulation with or without anesthesia	Thomas splint with skin traction from knee to ankle as emergency	Full abduction, extension, internal rotation (Wright's position)	Plaster splint extending to toes with short splint to opposite thigh or carried to opposite ankle, 12 to 15 weeks	Calliper and crutches 6 to 9 mos no weight bearing for 6 to 9 mos	12 to 15 wks	12 to 15 wks
	Ulna	Manipulation with or without anesthesia	Thomas splint with skin traction from knee to ankle as emergency	Usually slight abduction	Abduction plaster splint or traction in Thomas splint, 8 weeks or Maxwell-Ruth method	Calliper and crutches 4 to 6 mos, patient to be up as soon as union is firm	Immediate	Hip, 8 wks knee, 4 to 6 wks

**SCHEMATIC TABULATION OF TREATMENT OF FRACTURES—(Continued)**

Bone	Part of Bone	Reduction	Immobilization	Position	Secondary Splinting (Duration)	Convalescent Brace (Duration)	Physiotherapy (Time to Begin)	
							Massage	Active Motion
Lower	3 Shaft of Adult	Manipulation with or without anesthesia	Thomas splint with skin traction from knee to ankle as emergency	Hip flexion and knee flexion often necessary in fractures from trochanters to mid thigh. maintain normal anterior convexity of femur	Traction in Thomas splint (followed by 1 Skin traction (carried well above line of fracture), total traction, 5 to 9 weeks, or 2 Skeletal traction from condyles of femur (under proper conditions)	Caliper and crutches, 3 to 6 mos	Immediate	Knee, 2 to 4 wks
	b Children (not more than 6 yrs)	Manipulation with or without anesthesia	Thomas splint with skin traction from knee to ankle as emergency	1 Hip flexion, knee extension 2 Slight flexion of hip and knee	1 Overhead traction (on Bradford frame preferred), 6 weeks 2 Plaster spica (if reduction is satisfactory)	Plaster spica or long molded plaster side splint from axilla to below knee 4 to 6 wks	Not necessary	8 to 12 wks
	c Supracondylar	No manipulation, anesthesia if necessary for pain	Thomas splint with skin traction from knee to ankle as emergency	Hip flexion, knee flexion sufficient to maintain position	1 Skeletal traction from condyles of femur in Thomas splint (under proper conditions), followed by skin traction if necessary, total traction, 5 to 9 weeks 2 Plaster spica (if reduction is satisfactory) 3 Operation if necessary	Caliper and crutches, 3 to 6 mos	Immediate, if possible	Knee, 2 to 4 wks
Patella	5 Fracture into knee joint	No manipulation	Thomas splint with skin traction from knee to ankle as emergency	Hip flexion, slight knee flexion	1 Skeletal traction from head of tibia (under proper conditions) in Thomas splint, 5 to 9 weeks 2 Plaster spica (if reduction is satisfactory)* Suture 3 to 4 weeks	Caliper and crutches, 3 to 6 mos	Immediate, if possible	Early
	6 Separation of lower epiphysis	Manipulation with anesthesia (immediate)	Plaster toes to groin	Acute knee flexion		Plaster cylinder with gradual extension of knee	2 wks	3 to 4 wks
	7 With separation	No manipulation	Cabot posterior or similar splint (preparation for operation)	Extension	Operation after 3 to 8 days 1 Cabot posterior or similar splint 2 Molded plaster maltoil to buttock 1 to 3 weeks	Molded plaster cylinder posterior or Caliper 4 to 10 wks	Immediate if possible	As soon as skin wound healed

\* If the fracture is comminuted or the patient is unable to maintain the position of the knee, a plaster cylinder with gradual extension of the knee is indicated.

Patient	Without separation	No manipulation	Cabot posterior or similar splint (operation not necessary)	Same	Same, 1 to 3 weeks	Same	Same	1 to 2 wks
Fibula	a Without separation	Manipulation, if necessary, with or without anesthesia	Cabot posterior or similar splint	Extension	1 Manipulation with internal clamp if necessary, plaster toes to groin, 4 to 6 weeks 2 Skin traction in Thomas splint, 4 to 6 weeks	Caliper, 4 to 12 wks	Immediate, if possible	1 to 2 wks
	b Without separation	No manipulation	Plaster toes to groin	Extension	Same, 4 to 6 weeks	Caliper, 5 to 12 wks	2 to 7 wks	4 to 6 wks
Tibia	a With or without fibula	a Manipulation with or without anesthesia b Delbet method without anesthesia (excellent)	1 Molded plaster splint, toes to groin 2 Plaster toes to groin (with or without posterior wooden splint)	Slight knee flexion, foot at right angle, avoid rotation	Same, 6 to 8 weeks or skeletal traction in Thomas (especially in oblique fracture of lower third), 4 to 6 weeks, operation if necessary	Caliper or Delbet, 4 to 10 wks	1 to 3 wks Immediate, if possible	4 to 6 wks
	b Shift	Manipulation, if necessary, with or without anesthesia	1 Molded plaster splint, toes to knee or groin depending on level of fracture 2 Cabot or similar splint	Slight knee flexion	Same, 3 to 4 weeks, in fractures near head, special attention must be paid to external popliteal (peroneal) nerve	Not necessary	3 to 4 wks	2 to 4 wks
Ankle	a Inversion (adduction), Patt's, and outward rotation	Manipulation with anesthesia if necessary	Plaster toes to knee	1 Inversion (adduction), moderate flexion and lateral flexion (adduction) of foot with rotation of distal placements, especially posterior displacement	Same, 4 to 6 weeks	Short caliper if necessary Short caliper foot plate if necessary, Thomas heel (forward $\frac{1}{4}$ to 1 in, inner border used $\frac{1}{4}$ in)	1 day to 1 wk 1 day to 1 wk	2 to 3 wks 2 to 6 wks
	b With displacement	No manipulation if necessary with or without anesthesia	Plaster toes to knee	Plaster boot to knee or groin, operative manipulation necessary for those with displacement, 1 to 6 weeks*	Same, 1 to 6 weeks	Foot plate or Thomas heel	1 day to 1 wk	2 to 6 wks
Osteitis	a Without displacement	Manipulation with anesthesia if necessary	Pillow and slide splints temporarily	Slight plantar flexion and inversion (adduction), or plantar and knee flexion	Plaster boot to knee or groin, operative manipulation necessary for those with displacement, 1 to 6 weeks*	Foot plate or Thomas heel	2 to 3 wks	1 to 6 wks
	b With displacement	Manipulation with anesthesia if necessary	Pillow and slide splints temporarily	Right angle flexion and inversion (adduction)	Plaster boot with molding, 1 to 6 weeks, operation if necessary	Foot plate or Thomas heel	3 to 4 wks	1 to 6 wks
Metatarsals	a Not displaced	No manipulation	Molded plaster to tibial tubercle	Right angle flexion and inversion (adduction)	Same, 4 to 6 weeks	Foot plate or Thomas heel	3 to 4 wks	1 to 6 wks
	b Displaced	No manipulation	Pillow and slide splints	Right angle flexion and inversion (adduction)	Traction in bandjo splint, 1 to 6 weeks, or operation	Foot plate or Thomas heel	3 to 4 wks	1 to 6 wks

\* The conference considers this fracture very serious requiring skillful treatment, by operation if necessary

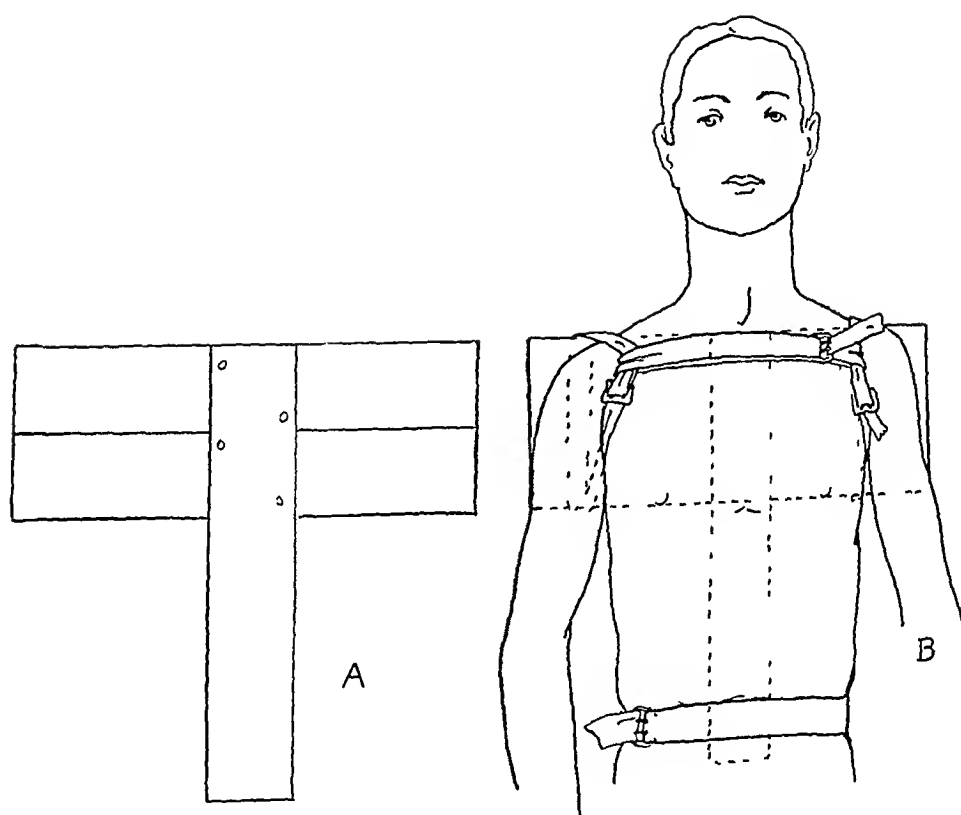


Fig 1—*A*, clavicular cross (made of splint board), the two pieces, the width of the shoulder, being tacked to a vertical piece reaching from the shoulder to the sacrum, *B*, method of application of clavicular cross (for purposes of simplification the padding is not shown) The surface of the splint in contact with the skin should be abundantly padded with cotton and covered with bandage The affected shoulder is lifted up, back and out and secured to the cross arms of the splint by straps or a figure-of-8 bandage The lower part of the vertical pieces is pushed in close to the sacrum and held by adhesive or buckle straps

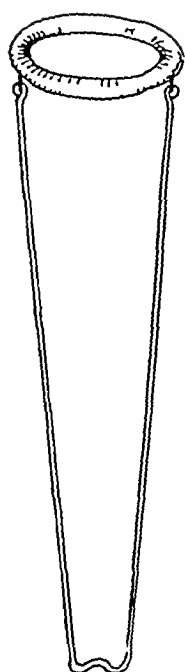


Figure 2

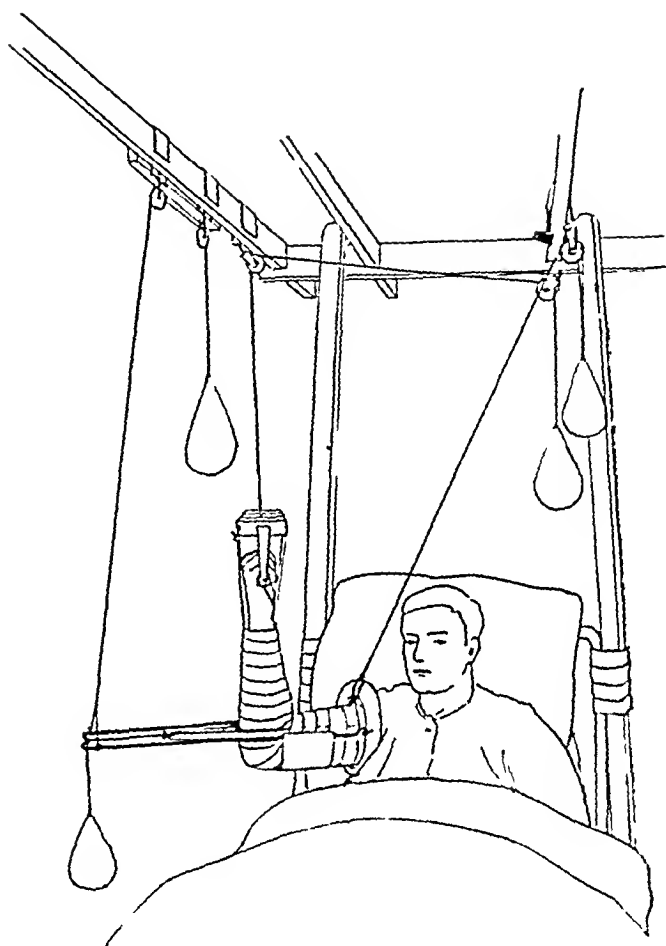


Figure 3

Fig 2—Thomas traction arm splint (Murray pattern) The ring is padded with felt and covered with leather and is hinged at its points of junction with the frame

Fig 3—Method of application of Thomas traction arm splint (Murray pattern) in fracture of the upper end of the humerus. Adhesive traction strips are applied to the upper arm traction being obtained by weight and pulley. The arm is supported on flannel or canvas strips pinned to the side bars of the splint. The elbow may be flexed as shown and suspended by means of additional traction strips to an overhead frame or it may be placed in the extended position in which case only one pair of traction strips extending from the wrist nearly to the axilla is used.



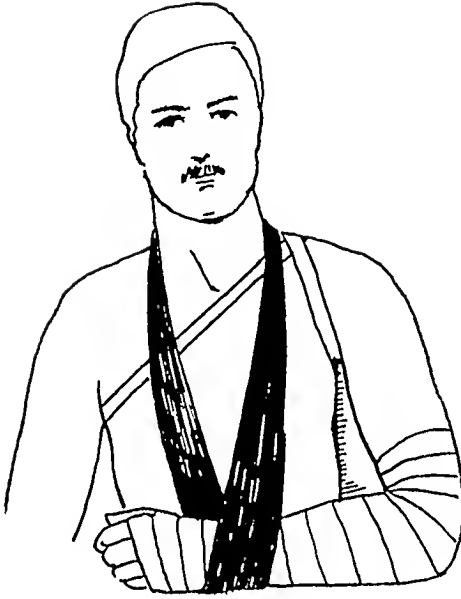


Figure 4



Figure 5

Fig 4—Axillary sweat pad and wrist sling, showing the narrow width of the sling

Fig 5—Plaster-of-Paris jacket, with shoulder spica and forearm casing holding the arm in the abducted position

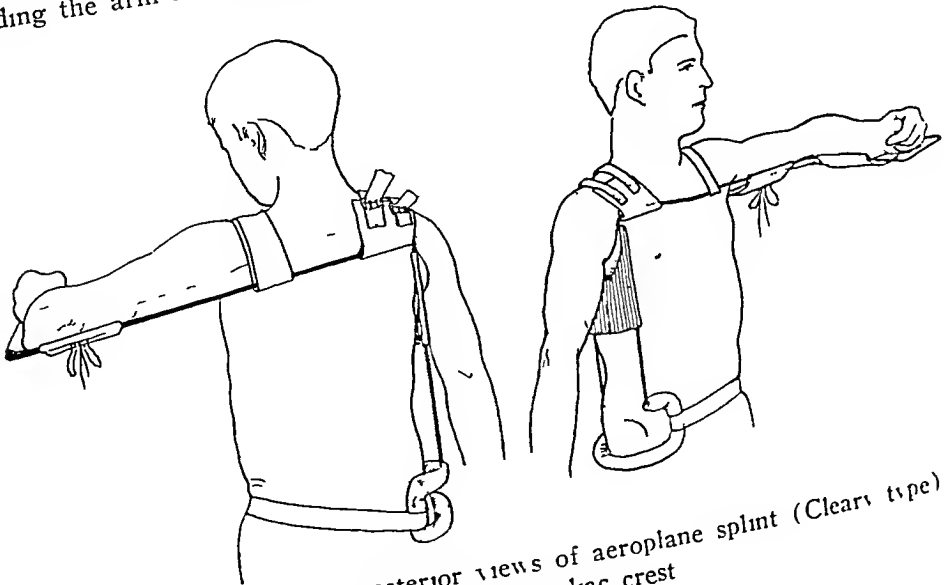


Fig 6—Anterior and posterior views of aeroplane splint (Clear type) the lower support of which rests against the iliac crest

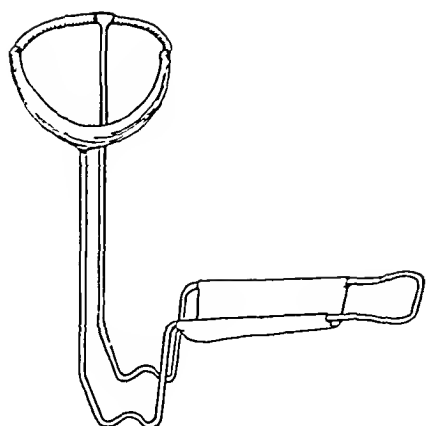


Figure 7

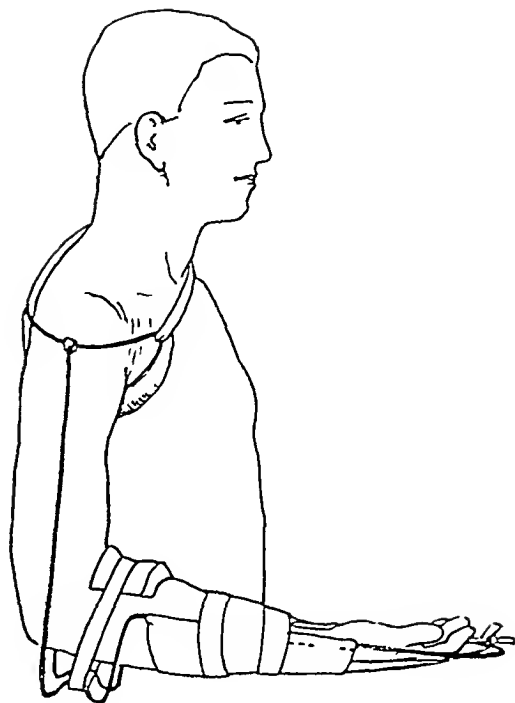


Figure 8

Fig 7—Jones humerus traction splint

Fig 8—Method of application of Jones humerus traction splint. Traction may be obtained as indicated by means of a strap passing over the upper end of the forearm, in which case a thick felt pad should be interposed between it and the skin. In other cases, traction is obtained by adhesive strips applied to the mesial and lateral skin surfaces of the upper arm.

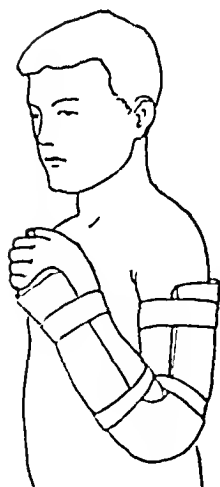


Figure 9

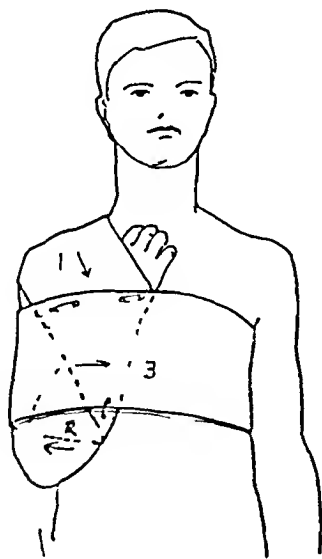


Figure 10

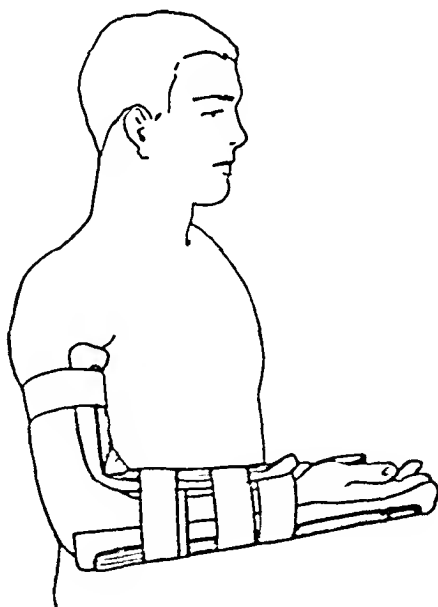


Figure 11

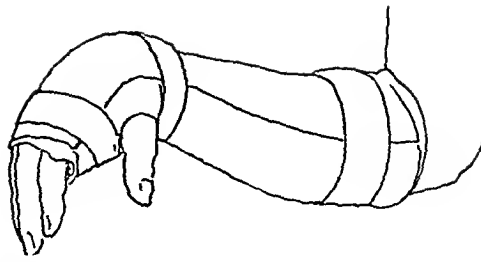


Fig 12—Colles' fracture plaster splint, illustrating the extreme position of pronation, adduction and wrist flexion in which it may be necessary to place the hand after reduction of certain cases of Colles' fracture

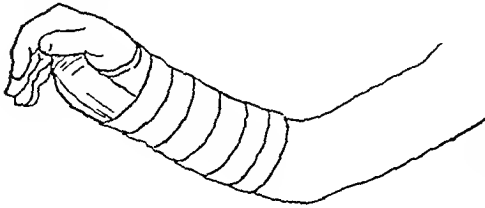


Figure 13

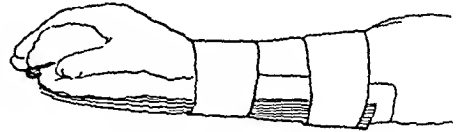


Figure 14

Fig 13—Plaster cock-up splint employed in certain cases of injury about the wrist

Fig 14—Long plaster cock-up splint holding the hand in the position of grasp, as required in fracture of the carpal scaphoid

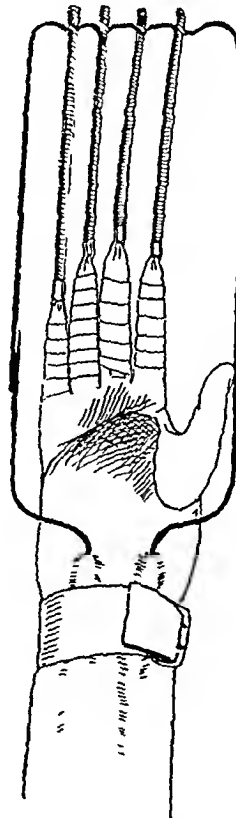


Fig 15—Banjo splint (indicated in fractures of the metacarpals with displacement and in certain fractures of the phalanges) The splint is made of a molded plaster strip applied to the forearm, in which is incorporated a wire frame appropriately bent to meet the indication The traction is obtained by adhesive strips fastened to the fingers and elastic tubing connecting these with the wire frame One or all the fingers may be included as necessary

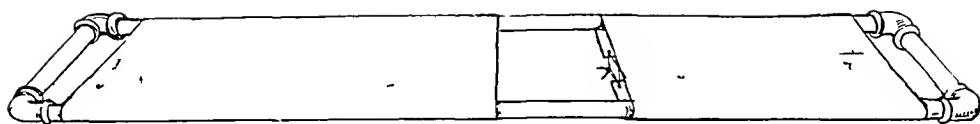


Fig 16—Bradford frame Canvas strips are laced across the frame, which is made of ordinary gas pipe, in such a way as to leave an appropriate interval for the buttocks under which the bed pan may be passed

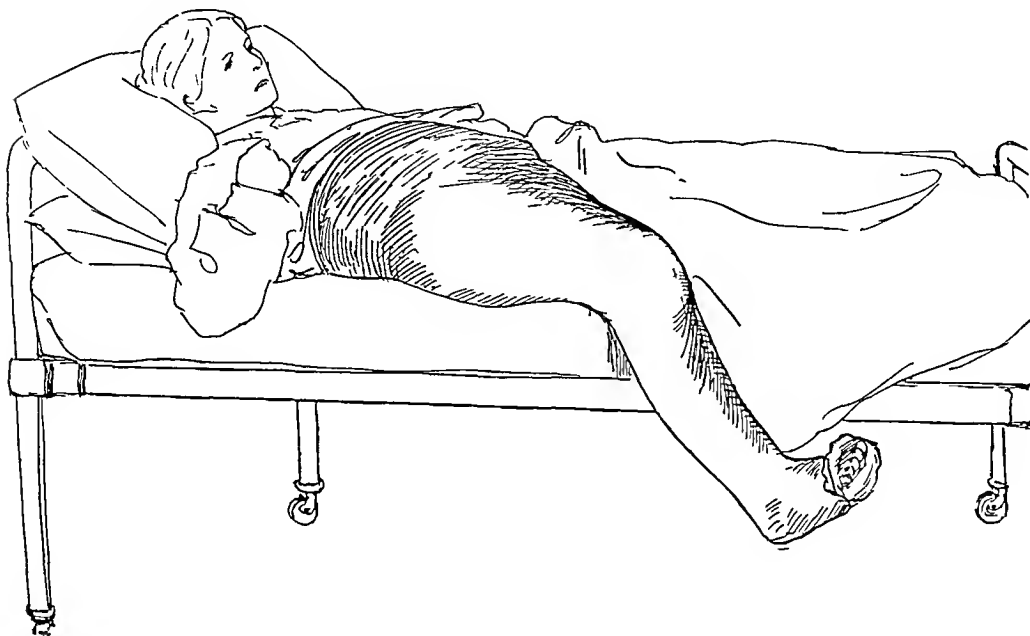


Fig 17—Long plaster spica extending from the toes to the axilla used in fractures of the neck of the femur to hold the hip in the position of abduction, extension and internal rotation

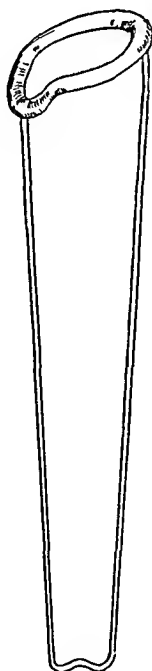


Fig 18—Thomas traction leg splint

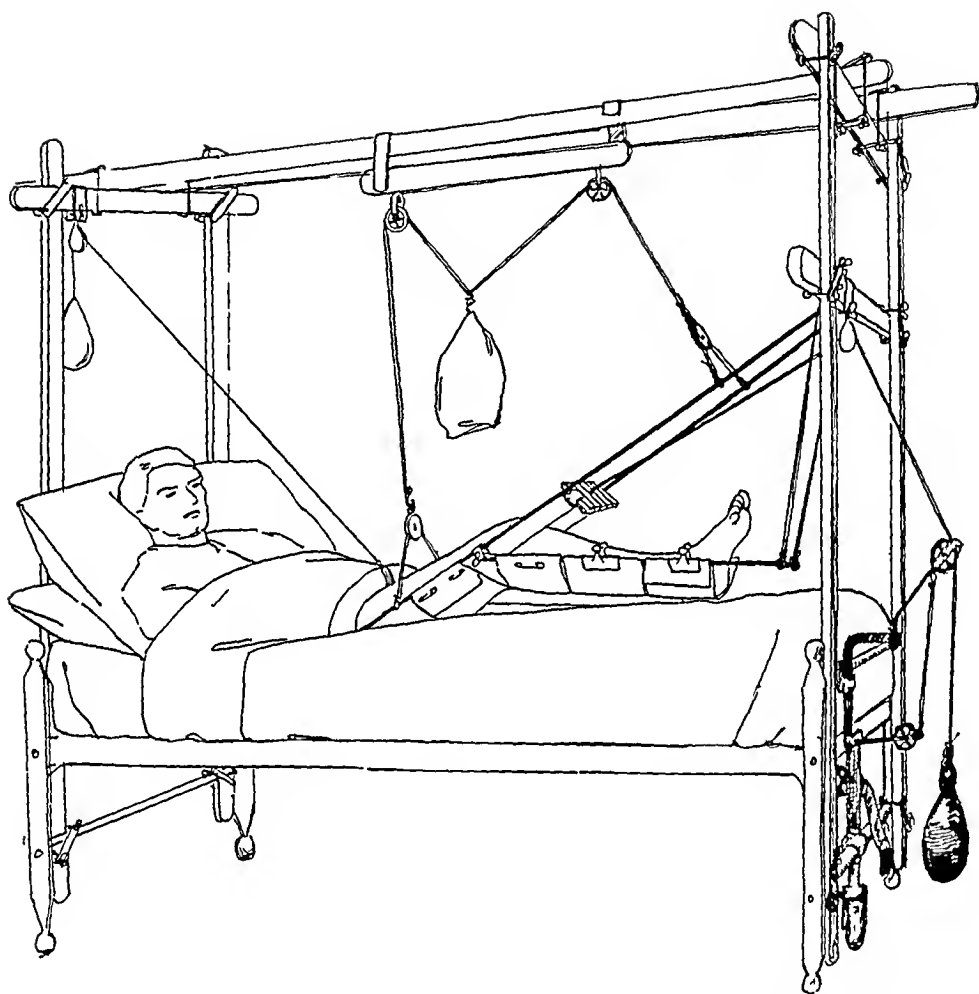


Fig 19—Balkan frame, illustrating the method of applying and suspending the Thomas traction leg splint with the hinged knee attachment

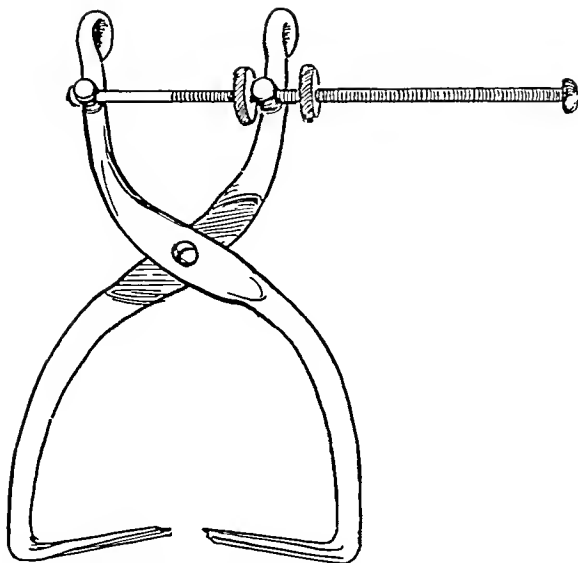


Fig 20—Calipers (Adams type) for direct skeletal traction on the femoral condyles

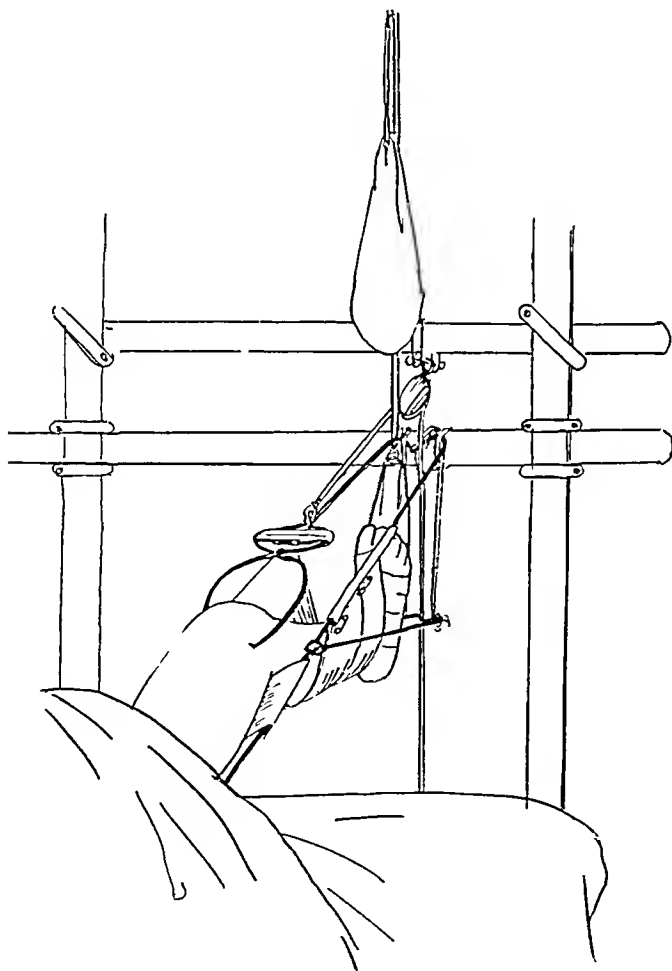


Fig 21—Skeletal traction in fractures of the femur The points are introduced on a horizontal plane one-half inch (13 cm) above and in front of the adductor tubercle

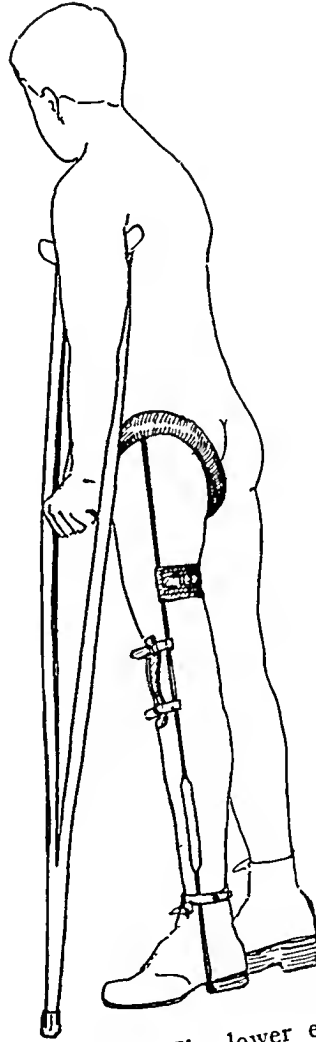


Fig 22—Thomas caliper splint The lower ends of the splint fit into the heel of the shoe, and part of the body weight is transmitted to the ground by the direct thrust of the rings against the tuberosity of the ischium The opposite shoe should be slightly elevated

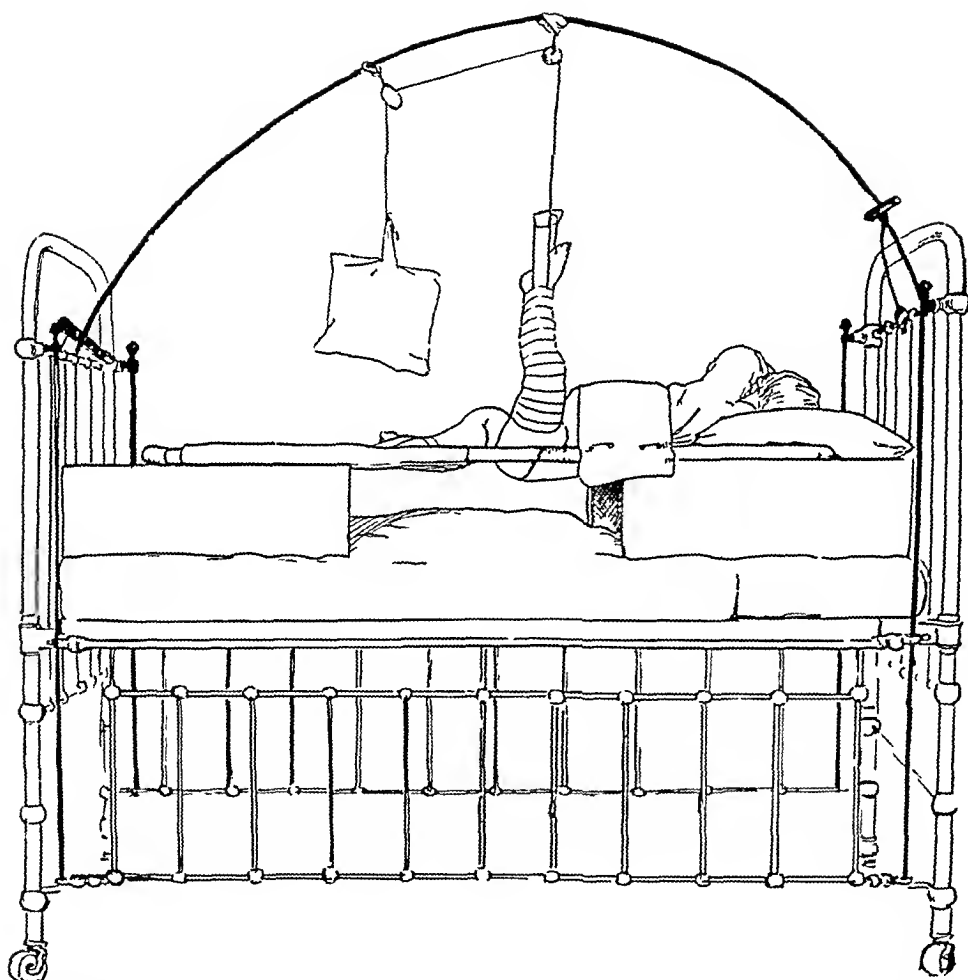


Fig 23—Rainbow frame The overhead traction as used in fractures of the femur in young children is illustrated The child is lying on a Bradford frame



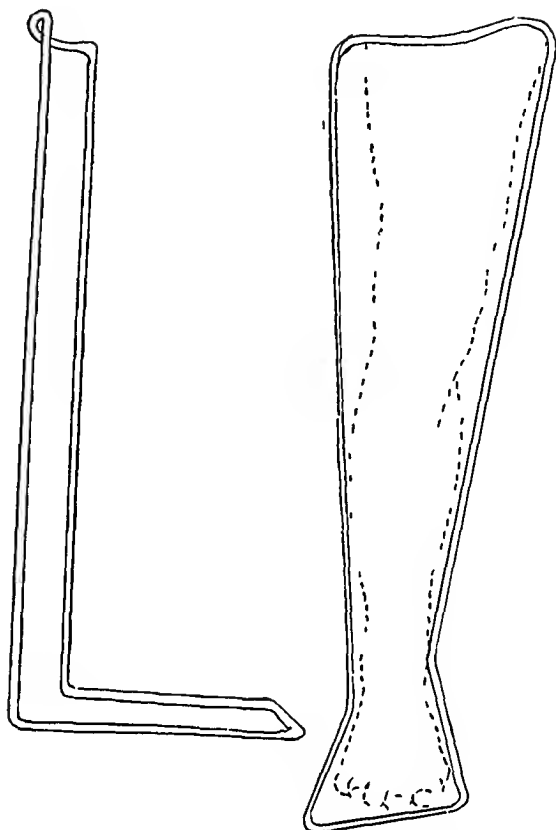


Fig 24—Cabot posterior wire splint

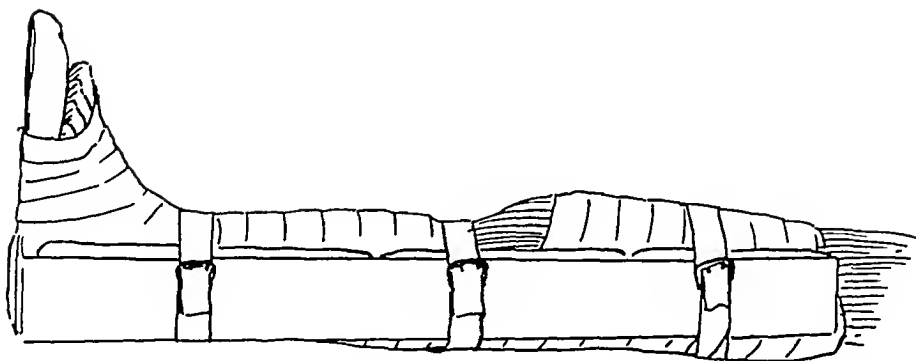


Fig 25—Cabot posterior wire splint applied with side splints in injuries about the knee

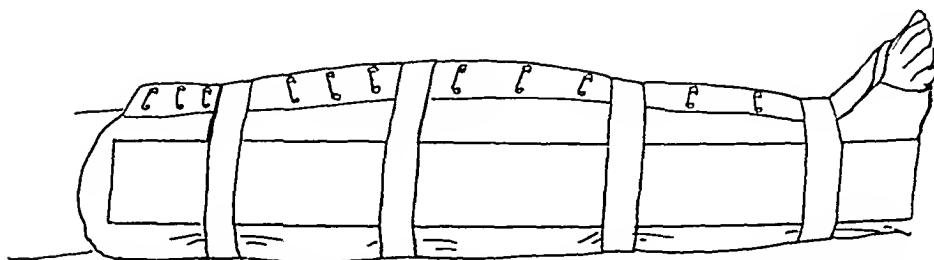


Fig 26—Pillow splint with lateral and posterior wooden splints, used as an emergency dressing in fractures of the leg

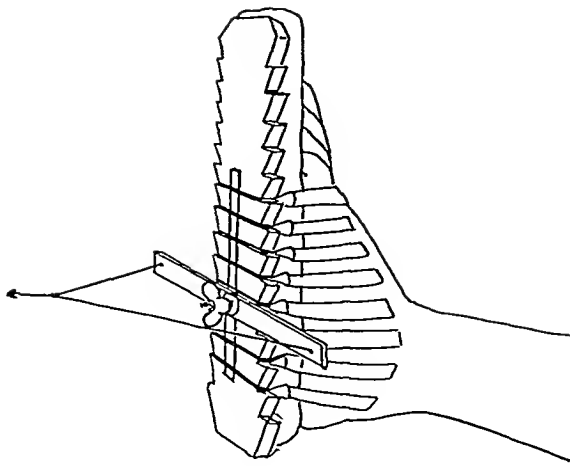


Fig 27—Method of application of Sinclair skate to obtain traction in certain fractures of the lower leg

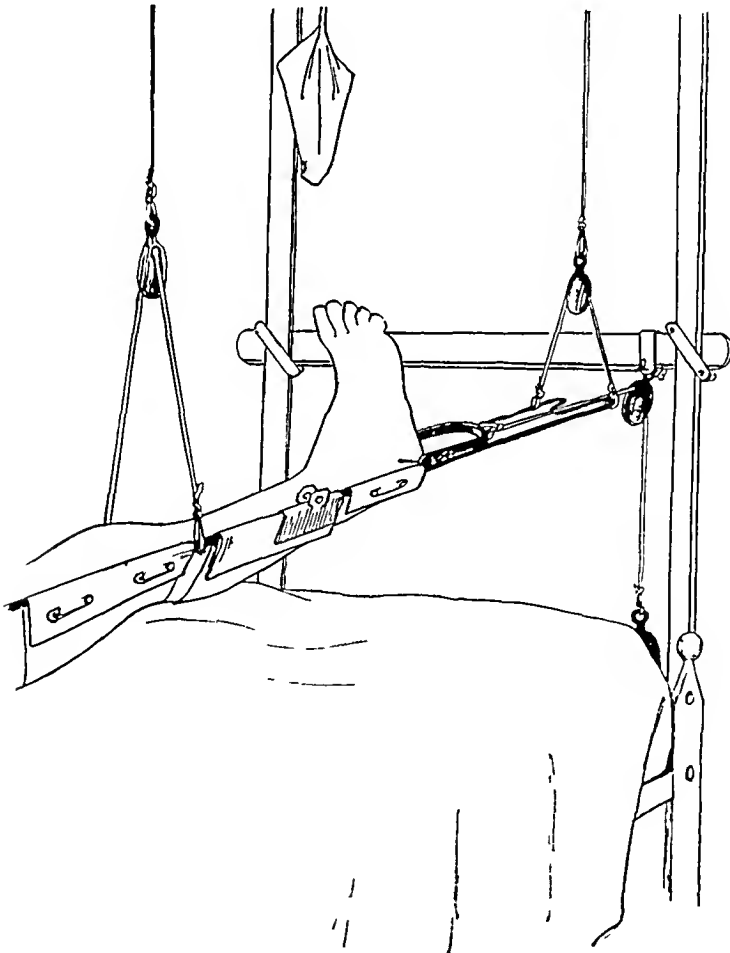


Fig 28—Skeletal traction on the os calcis. A Steinmann or similar steel pin is passed through the heel either over the top or through the center of the os calcis. To this pin, by means of an appropriate clamp traction is attached (used in connection with the Thomas traction leg splint)

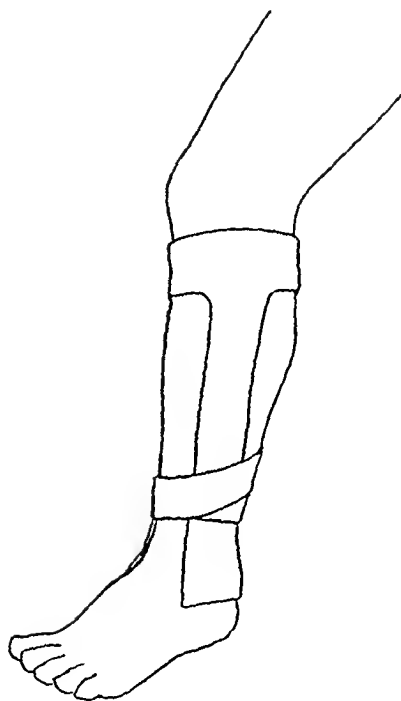


Fig 29—Delbet plaster splint Plaster strips are molded snugly without padding to the leg, one encircling the upper end of the tibia, two vertical strips on the mesial and lateral aspects of the leg, and one spiral strip holding them in position Weight is transmitted from the upper end of the tibia to the plaster strips and by them carried to the malleoli It is used as a convalescent brace

# NINETEENTH REPORT OF PROGRESS IN ORTHOPEDIC SURGERY \*

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C HERMANN BUCHOLZ, M D , H C LOW, M D ,  
MURRAY S DANFORTH, M D , LLOYD T  
BROWN, M D , PHILIP D WILSON, M D ,  
AND ARMIN KLEIN, M D

BOSTON

## CONGENITAL CONDITIONS

*Hypophyseal Lesions and Congenital Deformities*—Samaja,<sup>1</sup> reporting a case of congenital deformities of the lower extremities in a twin, associated with an abnormality of the sella turcica, suggests the possible relationship of congenital deformities to changes in the hypophysis

*Congenital Torticollis*—Frankel,<sup>2</sup> on the basis of sixty-one cases in which operation was performed without relapse, advocates early open operation by means of a transverse incision in the crease of the neck near the lower end of the muscle. The muscle is isolated and divided, and, if the fascia has been cut transversely, it is sutured longitudinally. Only one insertion of the muscle is divided if correction can be accomplished by this. A plaster cast is applied in overcorrection, with traction away from the shoulder operated on.

[ED NOTE—We believe it is nearly always wiser to divide both insertions and all contracted fascial bands if one is to avoid relapses. We also have encountered rather alarming symptoms of respiratory distress during, and sometimes following, the application of an overcorrecting cast while the patient is still under an anesthetic. We consider it safer and quite as satisfactory to retain the correction by head traction and sandbags for the first twenty-four hours at least, and then to apply the retentive cast when the patient is conscious.]

*Cervical Rib*—Taylor<sup>3</sup> has written a valuable paper on cervical ribs, with special reference to their surgical treatment. Their well known variation in size is no criterion as to the severity of the symptoms, and, with even the most rudimentary forms, there is usually found an aponeurotic band running from their tips downward to an attachment to the first true rib which may cause the same symptoms as a complete cervical rib.

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\* This Report of Progress is based on a review of 398 articles selected from 477 titles dealing with orthopedic surgery appearing in medical literature between Jan 21 1922, and May 21 1922. Only those papers which seem to represent progress have been selected for note and comment.

1 Samaja. *Chir d org di movimento* 5 690 (Dec) 1921

2 Frankel. *Arch f klin Chir* 118 228 (Nov 24) 1921

3 Taylor. *New York State J M* 22 97 (March) 1922

When these accessory ribs are present, the subclavian artery is placed at a higher level than normally, and when there is a bony connection between the cervical rib and the first true rib, the artery crosses the true rib just in front of the bony projection. The motor, sensory and vasomotor pressure symptoms are evident about the thirtieth year, often after some debilitating illness, and are caused by the impingement of the eighth cervical and first dorsal roots on the false rib, as these roots arch over its superior surface.

The sensory symptoms are usually first to appear, affecting the ulnar side of the forearm and hand, and may be expected to progress unless treatment is begun. Motor disturbances of insidious onset ensue, and atrophy of the small hand muscles, leading in some untreated cases to claw hand.

If the symptoms are of sufficient severity to demand operation for the removal of the accessory rib, the author advocates an anterolateral approach through an incision, beginning at the posterior border of the insertion of the sternomastoid, passing upward and outward to the border of the trapezius at an angle of 45 degrees with the clavicle. The cervical fascia is divided along the outer border of the plexus, which is separated from its bed posteriorly sufficiently to expose the rib and allow gentle retraction of the plexus forward. If the cervical rib is buried in the scalenus medius muscle, the palpation of the carotid tubercle serves as a guide. All muscular and ligamentous attachments to the rib are divided by sharp dissection in order to leave the periosteum intact. Care must be taken not to open the pleura. The head and neck are finally freed, and the intimate relationships of the seventh cervical root and the vertebral artery must be borne in mind. If the vertebral artery is wounded, it must be ligated at its origin. It is of great importance to have good illumination. As much of the rib as possible is removed, an attempt to enucleate cleanly the head and neck being made, though not always successfully. The aponeurotic extension must be divided. The wound is closed without drainage.

Taylor considers the advantages of this method of approach to be the following: (a) It is sufficiently free to make possible complete removal and control of bleeding. (b) It necessitates a minimum manipulation of the plexus. (c) The whole dissection follows natural lines of anatomic cleavage. (d) The scar is inconspicuous.

Five cases are reported and the article is well illustrated.

[ED. NOTE.—We commented in the last (Eighteenth) Progress on the work of Sir Harold Stiles on this subject, and the variations which occur in the formation of the plexus, in the so-called prefixed and postfixed types. In the postfixed or lower formation type, a "rocking" true first dorsal rib may cause the same train of pressure symptoms as a cervical rib.]

It is an interesting fact that the symptoms of pressure from cervical or first dorsal ribs ordinarily do not arise until the person is well advanced in adult life, Taylor says at about 30 years, and often following some debilitating illness. Since the anatomic variation has been present since birth and yet given rise to no symptoms until many years after full growth has been attained, there must be other factors which influence the onset of symptoms. We believe one of these factors is the faulty postures which often become more or less habitual in later life, and which, if unrelieved, may well cause a nerve to impinge on a cervical or even on a first dorsal rib, giving rise to the typical symptoms and signs above mentioned. Careful training in bodily mechanics and correct body and neck postures may bring about a subsidence of symptoms and this attempt in early cases might well be made before the rather difficult operative procedure is undertaken.

We have also encountered numerous cases of neuritic symptoms in the arms closely simulating rib pressure symptoms, even to small hand muscle atrophy, which were associated with a cervical arthritis. It has been possible to demonstrate this arthritis of the hypertrophic type in roentgenograms in patients between 30 and 40, as well as in older patients. Fixation of the neck by a Thomas collar and physiotherapeutic measures applied to the cervical spine have resulted in a disappearance of the arm symptoms. These cases emphasize the importance of taking lateral and anteroposterior roentgenograms of the whole cervical spine, as well as views of the cervical rib region.]

*Congenital Elevation of the Scapula*—Salaghi,<sup>4</sup> in reporting a case of congenital elevation of one scapula due to malformation of several ribs and an associated scoliosis, inveighs against the use of proper names in designating a condition. In his case, there were no abnormal attachments of the scapula to the spine, nor any muscular contractures. No operative procedures were required, and, if the scoliosis could have been corrected, the elevation of the scapula would have been corrected as well. To speak of the case as Sprengel's deformity would not properly describe the condition.

[ED. NOTE—The Editors in previous Reports of Progress have found occasion also to plead for the general abandonment of the use of proper names to describe lesions or diseases. We shall probably not escape from certain classical exceptions, sanctioned by long usage but Salaghi's point is well taken. Proper names, unless one is familiar with the literature, fail to suggest pathologic conditions and can never be descriptive.]

*König's Operation for Congenital Elevation of the Scapula*—Grauhan<sup>5</sup> has obtained such a satisfactory result from König's opera-

4 Salaghi. *Polichinico* 28 521 (Dec 15) 1921

5 Grauhan. *Arch f orthop* 19 408 1921

tion in a 17 year old patient with congenital elevation of the scapula that he considers the operation should have a wider employment. In his case, there was union of the transverse processes of the second and third dorsal vertebrae on the left to the mesial border of the scapula. The supraspinous portion of the scapula was prominent at the front of the neck, and the arm could be elevated only slightly beyond the horizontal plane. There was absence of the lower portion of the trapezius muscle. The incision was vertical, along the lower half of the mesial border of the scapula. The periosteum was split and elevated. The portion of the scapula united to the vertebral transverse processes was separated. The lower corner of the scapula was drilled, and a gauze loop passed through by means of which the whole lateral or external portion was drawn downward, 3 or 4 cm. The detached portion with its vertebral attachments was then reunited to the lateral portion by wire sutures. A strip of fascia was passed through the drill hole in the inferior part of the scapula and employed to anchor it in place. Gymnastic exercise and medicomechanical treatment followed. In a short time after the operation, the arm could be elevated to the perpendicular position.

*Congenital Dislocation of the Shoulder* —Coudray<sup>6</sup> reports two cases of luxation of the shoulder from arrested development or malformation, one in a child and one in an adult. The right arm in both cases was useless. In the child, the head of the humerus was nearly normal in shape. Massage and exercise were followed in the child by prompt and progressive improvement, so that the hand could soon be raised to the head. The malformations in the adult were too extensive to be influenced by this treatment.

*Spina Bifida Occulta* —Von Finck<sup>7</sup> has made a study of spina bifida occulta based on dissection findings in cadavers of new-born infants and in older living patients. He divides the cases into two groups: (1) those in which the spinous processes are rudimentary or lacking, and (2) those in which there is a lack of closure of the arches. These clefts tend to ossify before or at puberty, so that rarely does any defect last beyond this age. The condition is much more common than is generally supposed, and 35 per cent of those cases examined by the author showed signs of the lesion. The higher the defect, the more complete the cleft is likely to be, and the more severe are the symptoms. With the defects in arch closure in the upper vertebra, there often exists a fatty mass in the spinal canal. A foveola coccygea, hypertrichosis, pressure pain, club feet and scoliosis are the usual signs and

6 Coudray. *Bull de l'Acad de med* 86 262 (Nov 15) 1921

7 Von Finck. *Ztschr f orthop Chir* 42 65 1921

symptoms, and especially unfavorable is the prognosis of those cases in which a scar is found in the midst of the area of hypertrichosis. The author has collected forty-six cases in the corpses of the new-born.

*Madelung's Deformity*—Brandes<sup>8</sup> has reexamined two cases of Madelung's deformity of the wrist which he had described ten years previously. The patients were sisters, and their father had suffered from the same condition. The curve and expansion of the radius and the obliquity of the epiphysis had increased. He believes the condition to be usually congenital and to consist of a disturbance of growth of the epiphyseal cartilage. This disturbance of growth he considers primary, and the bending of the radius secondary. There may be other cases presenting a somewhat similar picture which may be the result of late rickets, in which the torsion of the radial shaft and its ulnar concave bending are primary.

*Congenital Luxation of the Patella*—Mouchet and Durand<sup>9</sup> report a case of bilateral congenital outward luxation of the patella successfully relieved by operation, in a boy of 10 years. They reconstructed the patellar apparatus by transplanting inward the tubercle of the tibia, after having drawn the patellar tendon and detached tubercle through a buttonhole in the anterior capsule of the knee joint.

*Congenital Dislocation of the Hip*—Thomas<sup>10</sup> reviews the problems presented by this condition on the basis of forty-four cases observed in a weekly orthopedic clinic during a period of eleven years. He believes heredity to be an important factor. He strongly favors the manipulative method, recognizing the occasional necessity for open operation. The control of the cases in the first three or four years of life he considers of great importance, and, in the selection of cases, he believes Ridlon's rule is the safest to follow, namely, to exclude from attempts at manipulation all patients under 2, with shortening of less than 1 inch (2.5 cm), and all patients over 5 with shortening of more than 2 inches (5 cm). The success of the procedure depends, in Thomas' opinion, on (a) the control of the early years of the child's life, (b) the ability of the surgeon to interpret the relation of the hip joint structures by his fingers, and (c) great gentleness of manipulation. Severe tearing or stretching of the tissues and forcing of the head into the acetabulum to deepen it, Thomas believes are responsible for the later deformation of the head and the arthritic changes which we now know are so common.

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8 Brandes. *Ztschr f orthop Chir* 42 20, 1921

9 Mouchet and Durand. *J de chir* 18 225 (Sept.) 1921

10 Thomas H B. *Congenital Dislocation of the Hip*. *J A M A* 78 32, (Feb 4) 1922



Blencke<sup>11</sup> confirms the interesting observation of Schanz that, since the war, in the German clinics, there has been a marked decrease in the number of cases of congenital dislocation of the hip, and a marked increase in the number of cases of congenital clubfoot. Congenital dislocation of the hip occurs about seven times more frequently among girls than among boys, and congenital clubfoot is twice as common in boys as in girls. The increase in male births since the war is held responsible for these phenomena.

*Clubfoot*—Hahn,<sup>12</sup> in discussing the etiology of equinovarus, has been impressed with the strong hereditary factor which Felsher estimated at 66.6 per cent, and with the large percentage of acquired types, varying, according to different observers, from 24 to 40 per cent, associated chiefly with inherited changes in the vertebrae, most commonly with spina bifida occulta. He also finds the condition twice as common in males as in females and a little more commonly bilateral than unilateral in the congenital cases.

Gaugele<sup>13</sup> reserves the employment of open operative procedures for the cure of clubfoot for those cases in which, after two or three thorough redressments in plaster, an obstinate adduction of the forefoot persists, especially adduction of the great toe. If, in these cases, the outer border of the foot is pressed upward, the great toe becomes plantar flexed and adducted. He believes this is due to the fact that since the outer border of the foot is longer in these cases than the inner, the base of the fifth metatarsal opposes any straightening of the outer convexity. In several cases, the author has removed the base of the fifth metatarsal and freshened the adjacent surface of the cuboid to obtain union. He has found it possible immediately to correct the foot after this procedure, the plaster being applied with the forefoot in strong abduction.

*Congenital Flatfoot Backward Luxation of the Fibula* Volkmann's *Deformity of the Ankle*—Brandes<sup>14</sup> reports an instructive case of a 7 year old child with congenital flatfoot, in whom the fibula was well behind the tibia and the tendon of the peroneus brevis luxated forward over the external malleolus. A transplantation of the tibialis anticus into the sustentaculum tali, performed a year previously, had failed to correct the position. Brandes transplanted the peroneus longus into the scaphoid, lengthened the contracted and forward placed peroneus brevis, and, after shortening the Achilles tendon, transferred its insertion mesially. A year and a half later, the foot was overcorrected.

11 Blencke Zentralbl f Chir 48 1625 (Nov 5) 1921

12 Hahn Ztschr f orthop Chir 42 151, 1921

13 Gaugele Arch f orthop 19 455, 1921

14 Brandes Ztschr f Orthop Chir 42 38 1921

and the varus was increasing so steadily that it was necessary to redress the foot again, shorten and displace forward the peroneus brevis and transplant the extensor longus hallucis into the fifth metatarsal

#### RICKETS, OSTEITIS FIBROSA, OSTEITIS DEFORMANS, ETC

*Rickets*—Cozzolino<sup>15</sup> well sums up the arguments against the theory that the absence of fat soluble vitamin A is the cause of rickets (1) While cod liver oil helps to cure rickets, the improvement is never so rapid as is the change in infantile scurvy when food rich in vitamins is given (2) Rickets may develop on any diet (3) Rickets shows a tendency to spontaneous (?) cure, while infantile scurvy (a disease known to be due to lack of vitamins) almost certainly will cause death unless treated (4) While cod liver oil will cure rickets, phosphorus alone will do the same (5) In experimental work on animals, rickets may develop in an animal on a diet rich in vitamin if he is confined closely, while it may not develop in an animal at liberty, though on a diet free from vitamins (6) Treatment with violet rays or heliotherapy cures rickets

Dodds,<sup>16</sup> as a result of experimental work, finds that the urinary diastase and fat content are greatly increased In seventeen cases of rickets, the mean was 154 diastatic units, the normal number being from 6 to 30 This diastatic power falls during convalescence The fat in the feces he also finds increased in his series, representing 75 per cent, as compared with 20 per cent in a series of nonrachitic children Dodds maintains that these findings suggest a pancreatic lesion in rickets, and that, as a result, there is a poor production of fatty acids and, consequently, a poor absorption of calcium

Hess<sup>17</sup> reviews the newer aspects of the rickets problem In addition to the two well recognized factors of improper diet and lack of sunlight, rate of growth and pigmentation of the skin are important in the development of rickets With a rickets producing diet, the disease will or will not develop, according to the dosage of light Rats fed with this diet do not have rickets if the proper dosage of the mercury vapor lamp is given, or if phosphorus is administered The pigmentation of the skin affects the potency of light If groups of white and black rats are fed a rickets diet and given a quartz mercury light treatment, the white ones will not develop rickets, while the black ones will do so The darker the skin the more light is required to protect against rickets The relative importance of these factors is not

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15 Cozzolino *Pediatrics* 30 97 (Feb 1) 1922

16 Dodds *Brit M J* 1 511 (April 1) 1922

17 Hess A F *Newer Aspects of Rickets Problem J A M A* 78 1177 (April 22) 1922

yet satisfactorily understood. Experiments were carried out in a large institution for the care of children and in the laboratory which seem to indicate that the fat soluble vitamin is not the dominating factor. Animals deprived of it develop an osteoporosis, but not a true rickets. The examination of the blood of the infants revealed that clinical rickets may precede the decrease in the inorganic phosphates in the blood, which becomes lowered later as the signs seen in the roentgenograms appear. There is some factor which determines its level.

Hess,<sup>18</sup> working with Pappenheimer, has demonstrated that rachitic lesions which develop regularly in rats on a diet adequate in calcium, but low in phosphorus, were prevented by short exposures to direct sunlight. They calculated that this protection is equivalent to the addition of at least 75 mg of phosphorus to the diet, in the form of basic potassium phosphate.

Powers, Park, Shipley, McCollum and Simmonds<sup>19</sup> have been able, in rats fed on a rickets producing diet, to protect them from the development of the disease by exposing them to the irradiation of a mercury vapor quartz lamp. It is possible to say also that such irradiations affect the whole organism and not the skeleton alone. There is a favorable effect on muscular development, storage of fat, growth of the hair, sexual development and reproductive power. As far as they have been able to discern, the effects of the irradiation from the mercury vapor quartz lamp in bringing about an efficient utilization of the substances which are directly or indirectly concerned with ossification and calcification, and in promoting general bodily vigor, are in no way different in respect to these matters from the action of cod liver oil or sunlight.

Huldschinsky<sup>20</sup> reports the clinical and roentgen-ray cure of a case of severe rickets in a child of 3 by eighteen exposures to soft roentgen rays in a period of two months. He does not advocate this somewhat dangerous method of therapy, when equally good results may be obtained from other harmless forms of light, rich in ultraviolet rays, but looks upon the results as experimentally important.

Shipley, Park, McCollum and Simmonds,<sup>21</sup> as a result of their experiments, have come to the conclusion that there are probably two forms of rickets. One is characterized by a normal or nearly normal

18 Hess, A. F., Unger, L. J., and Pappenheimer, A. M. *J. Biol. Chem.* **50**: 77 (Jan.) 1922.

19 Powers, Park, Shipley, McCollum and Simmonds. *Bull. Johns Hopkins Hosp.* **33**: 125 (April) 1922.

20 Huldschinsky. *Ztschr. f. orthop. Chir.* **42**: 240, 1922.

21 Shipley, P. G., Park, E. A., McCollum, E. V. and Simmonds, N. Is There More Than One Kind of Rickets? *Am. J. Dis. Child.* **23**: 91 (Feb.) 1922.

blood calcium and a low phosphorus (low phosphorus rickets), and the other by a normal or nearly normal blood phosphorus, but a low blood calcium (low calcium rickets). They suggest the possibility that there may be a true renal rickets, and that the rickets accompanying the alimentary anemias may represent a somewhat different kind of disturbance in metabolism from that which is present in the ordinary forms of the disease.

The same authors,<sup>22</sup> by feeding animals with a diet low in phosphorus and in an undetermined organic substance and relatively high in calcium, have uniformly noted a disappearance of calcium from the epiphyseal cartilages and the metaphyses, as seen in the roentgenograms. The reappearance of this provisional zone of calcification, after the addition of any substance to the rickets producing diet, constitutes a test for the calcium depositing value of their substance. For example, cod liver oil to the extent of 2 per cent by weight of the diet causes this provisional zone of calcification to be reformed in five days, 0.4 per cent of cod liver oil fails to cause this zone of calcification to appear, and 1 per cent causes a less complete calcium deposition in five days than 2 per cent. This test may be utilized to determine the efficacy of any agent to heal the rachitic lesions.

Shipley<sup>23</sup> again emphasizes the fact that the normal calcium phosphate ratio in the blood is altered in rickets. The normal calcium content is from 9 to 11 mg. for each hundred cubic centimeters of blood, the normal phosphates are from 4 to 6 mg. for each hundred cubic centimeters. If the calcium falls below 5, there is tetany either latent or manifest, that is, in cases of rickets with latent tetany there is marked blood calcium reduction.

Jacobsen<sup>24</sup> reports excellent results following manual correction of rachitic deformities of the legs, after the application of a plaster cast to the entire limb. This cast is allowed to remain on from six to nine weeks, depending on the age of the child. He considers all active and sclerosing types to be suitable for this method. The correction often requires much force, and frequently slight infractions of the cortex occur. After correction, a new plaster cast is applied for four weeks and cod liver oil and phosphorus are administered. Massage is instituted, and the child is allowed to be up in two weeks more.

*Osteitis Fibrosa*—Young and Cooperman,<sup>25</sup> after reporting a case of the generalized form of this disease in a colored woman of 21 (first

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22 McCollum, E. V., Simmonds, N., Shipley, P. G. and Park, E. A. *J. Biol. Chem.* **51**: 41 (March) 1922.

23 Shipley. Paper read before Medical Society of State of New York April 1922.

24 Jacobsen. *Munchen med. Wchnschr.* **68**: 920 (July 22) 1921.

25 Young, I. K., and Cooperman, M. B. *Ann. Surg.* **75**: 171 (Feb.) 1922.

case reported in this race), conclude that under the term osteitis fibrosa should be included benign bone cysts, giant-cell sarcoma of the epulis type, hemorrhagic osteomyelitis and the generalized form, or von Recklinghausen's disease. They consider that these conditions represent a pathologic entity characterized by metaplasias of bone. They believe that local osteitis fibrosa and benign bone cysts are dependent on trauma and that the generalized form must represent grave nutritional disturbances, possibly caused by endocrine dysfunction, chronic low grade infection and a faulty calcium metabolism.

Morton<sup>26</sup> has made a very complete report of a case of the generalized form in a man of 23, who had suffered from the disease for many years and who presented an extreme deformity of the right femur and lesions demonstrable by the roentgen rays in the skull, right humerus, radius and ulna, and both tibias and fibulas. Two osteotomies of the right femur were performed after a failure to correct the deformity by wedging a plaster-of-Paris bandage. The femur united well, and six months later, the patient was using his corrected leg freely.

*Brittle Bones and Blue Sclerotics*—The association of blue sclerotics with brittle bones is said to have been first described by Eddowes in 1900. He suggested that the transparency of the sclera indicated a lack of quantity or quality of the fibrous tissue forming the framework of various organs of the body and probably explained the lack of spring and toughness in the bones. The importance of heredity has been repeatedly observed, and Alexander<sup>27</sup> reports a case of fragilitas ossium associated with blue sclerotics in four generations. Mallard<sup>28</sup> also reports a case of fragilitas ossium (or osteopsathyrosis) in a child of 3, with seven recent fractures, which had occurred without pain and which healed promptly, leaving some swelling in the region of the break. There was present in his case also a striking degree of blue in the sclerotics.

*"Marble Bones"*—Schoenberg, in 1904, described a peculiar affection which has been termed "marble bones," consisting of increased calcium deposit in the bones and increased fragility. Schulze<sup>29</sup> reports the seventh case with the result of a necropsy. This revealed marked over-deposition of calcium in the diaphysis, a narrowing of the marrow space, irregularities of the epiphyseal lines, and club-shaped disappearance of the diploe and narrowing of the canals for the vessels and nerves of the skull which in his case explained the optic nerve atrophy. There were deposits of calcium in most of the organs.

26 Morton, J. J. Generalized Type of Osteitis Fibrosa Cystica. Arch Surg 4 534 (May) 1922.

27 Alexander, I. B. Brit M J 1 677 (April 29) 1922.

28 Mallard. Pediatría 30 75 (Jan 15) 1922.

29 Schulze. Arch f klin Chir 118 411 (Nov 24) 1921.

## TUBERCULOSIS

*Tuberculosis of the Joints of the Upper Extremity*—Valtancoli<sup>30</sup> reviews the cases of tuberculous joint disease of the upper extremity which have been treated at the Istituto Rizzoli for the last twenty-one years, 1899-1920. There were eighty-six of these cases, a very small number when compared to the number of cases of tuberculous joint disease of the lower extremity. Only hospital ward cases are included, however, and many cases were ambulatory. Forty-one of the eighty-six cases were disease of the elbow, twenty-eight of the wrist, and seventeen of the shoulder. For the first eleven years of the period, the treatment had been largely surgical, consisting of total or partial resections. For the last ten years, it has been largely conservative, consisting of fixation and heliotherapy. The results of both forms of treatment were evidently good, but it is interesting to know that conservative treatment has largely replaced the operative in this important institution where such able surgeons as Codivilla and his successor Putti have been responsible for the care of patients.

*Tuberculous Tenosynovitis of the Hand*—Kanavel,<sup>31</sup> at the meeting of the Western Surgical Association, called attention to the fact that tuberculosis of the tendon sheaths of the hand may occur in both the dorsal and palmar groups. An early diagnosis, based on the suggestive fulness over the sheaths, the slight stiffness of the fingers, and the inability to flex or extend them completely, is of great importance. If one waits before operating until rupture has taken place or there has been a destruction of the tendon which will ensue if the process is long continued, the results are likely to be unsatisfactory. The operation should be thorough, completely removing all tuberculous tissue, even including the tendon if necessary, in which case a plastic operation will be required to restore function.

Ehner<sup>32</sup> describes a case of tuberculosis of the palmar fascia closely resembling Dupuytren's contracture in a girl, aged 20 years. The disease tissue was excised. This showed tuberculous granulations, a little caseous material and a marked tendency to the formation of connective tissue.

*Vertebral Tuberculosis, Pott's Disease*—Matheis,<sup>33</sup> on the basis of twenty cases of tuberculous spondylitis in adults treated since 1919, considers the result of conservative treatment to be discouraging and the result of treatment by the bone graft method much better. He

30 Valtancoli. *Chir. d. org. di movimento* 5:652 (Dec.) 1921.

31 Kanavel. A. B. *Tuberculous Tenosynovitis of the Hand*. abstr. I. A. M. A. 78:304 (Jan. 28) 1922.

32 Ehner. *Wien. klin. Wchnschr.* 34:252 (May 26) 1921.

33 Matheis. *Wien. klin. Wchnschr.* 34:557 (Nov. 17) 1921.

believes the operation is advisable only in adults, since in children we may expect an ankylosis from conservative treatment, and the length of time taken for a cure is not a serious matter. His conclusions are similar to those of Baer,<sup>34</sup> who reports the results of fifty operations by the Albee method, performed at least two years previous to the report. Those patients operated on during the period of growth showed less than 33 per cent of good results. Those operated on after 16 showed 90 per cent of good results. All of the grafts in the cervical region showed poor results. The longer the duration of the disease before the operation, the better the results, but the greater the kyphosis at the time of operation, the least likelihood of cure. He believes artificial support is necessary for at least six months after the operation in adults and for from two and one-half to three years in children. His conclusions are that in infancy the operation is of questionable value, that it may be of value in carefully selected cases in the growing period of 6 to 16 years, but must be considered only as an aid to proper mechanical treatment, that in adults the operation is indicated in the majority of cases, but that mechanical support should be employed for at least six months after the operation.

Cofield<sup>35</sup> calls attention to hypertrophic bone changes which take place in a certain number of cases of tuberculous spondylitis during the active stage of the disease. He has demonstrated these changes in ten out of 100 cases which he has studied. These changes he looks upon as nature's attempt to ankylose the diseased area by means of bony bridges. It seems to be peculiar to the adult form, and Cofield considers that it suggests the essential soundness of the principle of operative fixation by means of a fusion operation or a bone graft.

*Multiple Foci in Tuberculous Spondylitis*—Peabody,<sup>36</sup> in an examination of 312 roentgenograms of tuberculosis of the spine, discovered thirteen in which there was more than one separate focus of disease. Since many of the cases showed only the area of suspected disease, Peabody believes the actual percentage to be higher than this 4 per cent perhaps as high as 8 per cent.

Wimberger<sup>37</sup> also reports a case of a boy with a healed process involving the second and third lumbar vertebrae and an active process in the seventh, eighth and ninth dorsal vertebrae.

[ED. NOTE—These cases are instructive and the Editors have met several in which two separate areas of disease existed, one of which was unsuspected at the time an ankylosing operation on the more active

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34 Baer W. S. Bull. Johns Hopkins Hosp. **33** 140 (April) 1922.

35 Cofield R. B. I. Bone & Joint Surg. **4** 332 (April) 1922.

36 Peabody C. W. Ann. Surg. **75** 95 (Jan.) 1922.

37 Wimberger. Wien. klin. Wchnschr. **35** 102 (Feb. 2) 1922.

focus was performed, but which became active later and required a second ankylosing operation. It is evidently important before subjecting the patient to an operation, to study carefully roentgenograms of the entire spine in the search for unsuspected early or inactive areas of disease.]

*Diagnosis of Early Hip Joint Disease*—Rugh<sup>38</sup> considers the most important indications of early tuberculous hip joint disease to be (1) the history, (2) the intermittent limp, (3) the muscular spasm, (4) the limitation of motion in all directions, (5) the position of the limb, i. e., apparent shortening or lengthening due to permanent abduction, adduction or flexion, (6) the atrophy of the muscles, (7) the referred pains, to the knee especially, (8) the night cries, (9) the slight elevation of temperature, and (10) the roentgen-ray findings.

Rugh says that the conditions most likely to be mistaken for tuberculous coxitis are (1) rheumatism, (2) growing pains, (3) synovitis, (4) genital irritation, (5) epiphysitis, (6) acute rickets, (7) infantile scurvy, (8) contraction of the psoas muscle, (9) disease of the spine or knee, (10) coxa vara and coxa plana or Legg Calve, Perthes' disease.

[ED NOTE—If under the term rheumatism, Rugh includes those very frequent cases of hip joint pain and limitation of motion which arise from digestive upsets and intestinal absorption, we should agree in placing this first in his list of conditions which closely resemble early tuberculous coxitis. In fact, it is our experience that often one cannot make a positive diagnosis in a case of this sort at the first visit. They may present an inconclusive history, an intermittent limp, muscle spasm, limitation of motion in all directions, abduction, adduction and flexion, referred pains, night cries, slight elevation of temperature. Early tuberculous coxitis may show little or no muscular atrophy and inconclusive roentgenologic findings, as do these cases. We believe this train of hip joint symptoms from intestinal infections or absorption of toxins are comparatively common. We see more cases of these fleeting disturbances than of true tuberculous coxitis. They are easily mistaken for the more serious condition, but they seem to demand only freedom from weight bearing and thorough evacuation of the bowels by means of abdominal massage, laxatives, and sometimes even enemas after which the symptoms disappear very quickly to be repeated if the intestines again become clogged. The absence of atrophy and the rather sudden though often painless onset of the limp and joint motion limitation should make us suspect this nontuberculous coxitis and refrain from too completely fixing the joint and unduly alarming the parents. In these doubtful cases, it is safer to insist on recumbency and while the symp-

<sup>38</sup> Rugh, J. T. New York M. J. 115:256 (March 1) 1922.



toms exist, treat the case as if it were the more serious condition, but surely not condemn the child to permanent fixative treatment until we are sure of the diagnosis

*Excision of Os Calcis for Tuberculous Osteitis*—Wakeley<sup>39</sup> reports the late result of a complete excision of the os calcis for tuberculosis. The operation was performed twenty-one years ago when the patient was 20 years old, and he can walk several miles without discomfort or limp. The heel has filled up with a large pad of fat.

*Diagnosis in Tuberculosis of Bones and Joints*—Kisch<sup>40</sup> has written a useful paper dealing with the frequent blunders that are made in the diagnosis of tuberculosis of the bones and joints. He points out that a patient with a gonococcal joint will usually remember the day of onset and describe more pain than will a patient with a tuberculous joint. The roentgenogram of a tuberculous joint will show trabeculae more clearly than a gonococcal joint, in which they are less distinct and the shadow more hazy. A sternoclavicular joint disease is more often syphilitic than tuberculous. A flocculent exudate on aspiration speaks for tuberculosis rather than a syphilitic or gonococcal effusion. The most conclusive evidence is obtained by animal inoculation of the exudate.

*Treatment of Bone and Joint Tuberculosis by Injections of Tubercle Bacilli Split Products*—Joannovics showed that split products of tubercle bacilli fermentatively obtained had the property of disorganizing, breaking down and attacking injured tissue. In animal experimentation, they caused a production of normal granulation tissue by their effect on the diseased granulation tissue. Stracker<sup>41</sup> has employed injections of these products to the limit of reaction, every second day, for two months. Tenderness and pain on motion disappeared, except in the severe cases, but no rapid or complete disappearance of symptoms occurred. At first there seemed to be an increase in the discharge from sinus cases. He realizes that his experience is too short and limited to be conclusive, but he believes he has demonstrated at least that no very rapid cures may be expected and he questions whether, in his healed cases, the element of time was not more important than the specific medication.

#### SYPHILIS

*Bone Changes in Congenital Syphilis*—Dembo, Litchfield and Foote,<sup>42</sup> writing on the foregoing subject, consider the diagnosis a comparatively

39 Wakeley, C. P. G. *Brit. J. Surg.* 9: 553 (April) 1922.

40 Kisch. *Arch. f. klin. Chir.* 118: 481 (Nov. 24) 1921.

41 Stracker. *Wien. klin. Wchnschr.* 34: 569 (Nov. 24) 1921.

42 Dembo, L. H., Litchfield, H. R., and Foote, J. A. *Bone and Joint Changes in Congenital Syphilis*, *J. A. M. A.* 78: 319 (Feb. 4) 1922.

easy one to make if the history is carefully obtained from the mother and search made for other manifestations of the disease, in which search the roentgen ray is of special value. The Wassermann reaction is of marked positive, but less negative, value. Syphilitic epiphysitis is often of very acute onset, with swelling, tenderness and pain. Syphilitic dactylitis is usually multiple, while tuberculosis involves ordinarily one finger alone and the first phalanx of the index finger is its most common seat.

Among forty-three infants suffering from inherited syphilis, Thoenes<sup>43</sup> found the distal epiphyses of the ulna and radius were the favorite spots for localization of the syphilitic changes, but they were not completely symmetrical. He noticed also that roentgenograms seemed to reveal more severe bone lesions in cases free from cutaneous signs of the disease.

Skinner,<sup>44</sup> in an article on the roentgenology of bone syphilis, comments on the fact that the roentgen-ray records are rarely paralleled by the clinical symptoms. The lesions shown by the roentgenograms are much more extensive than the clinical findings. He calls attention to the fact that the essential process in bone syphilis is constructive.

#### PARALYSIS

*Value of Colloidal Gold Reaction in Acute Epidemic Poliomyelitis*—Regan and Cheney<sup>45</sup> made the colloidal gold test of seventy-four specimens of spinal fluid obtained from twenty-one cases of acute epidemic poliomyelitis. The fluids were examined at intervals varying from the fourth to the one hundred and twenty-third day of the disease. The predominant type was the myelitic, most of the cases presenting symptoms of moderate or marked polyneuritis. The authors are fairly well convinced that a relationship exists between the duration of the positive colloidal gold curve and the acute inflammatory stage of the malady. They have been led to believe that when the reduction of the gold chlorid becomes normal the acute period of the disease is over. If this is so, the reaction may well be of value as an index of the appropriate time for passing from the treatment of complete rest to the more energetic physiotherapy. They have noted also that with the gradual subsidence of the colloidal gold curve there is usually a corresponding improvement in the patient's general condition and in his paralytic and meningeal symptoms. No close relationship was found between the cytology and chemistry of the spinal fluid and the gold

43 Thoenes. Arch f Kinderh. 70 252 (Jan 28) 1922

44 Skinner E. H. Am J Syphilis 6 58 (Jan) 1922

45 Regan, J. C. and Cheney G. W. H. Am J Dis Child 23 107 (Feb) 1922

chlorid reaction The chemistry and cytology of the spinal fluid seems to return to normal almost as soon as the acute symptoms have subsided, while the gold chlorid curve returns to normal more slowly, remaining elevated usually after other pathologic signs in the spinal fluid have disappeared The colloidal gold test proved in their hands of no special prognostic value in the fatal cases It was usually more marked, but did not differ sufficiently in the first few weeks from the nonfatal acute cases to be helpful

*Poliomyelitis with Cortical Involvement*—Clark,<sup>46</sup> in an analysis of thousands of cases of epilepsy, has encountered only three in which poliomyelitis has been followed by enduring epilepsy A disposition of the epileptic type was present in all of these three before the attack of poliomyelitis, one of them being a typical epileptic in temperament and mental makeup Clark believes that the predisposition to the disease existed before the paralytic attack He can offer no surmise as to what the meningeal or cortical lesion coincident with the poliomyelitis represents

*Poliomyelitis and Epidemic Encephalitis*—Cadwalader<sup>47</sup> states that clinical phenomena presented by certain nonparalytic cases of acute poliomyelitis, influenza and epidemic (lethargic) encephalitis are so similar that one must depend largely on the knowledge as to whether an epidemic of one or the other is prevalent In poliomyelitis, the seventh cranial nerve is most often affected, while in epidemic encephalitis the third nerve is commonly involved The author considers epidemic (lethargic) encephalitis an infectious disease possessing a separate and distinct entity It differs from poliomyelitis particularly in the long survival of the virus in the central nervous system Its course, therefore, may be very irregular and exhibit remissions and exacerbations extending over months or years The diagnosis between the two conditions, however, will often be impossible if only the subjective and objective signs are considered

*Paralysis from Section of Spinal Cord*—Lhermitte and Pagniez<sup>48</sup> report the case of a child of 13 who sustained a complete section of the spinal cord in the dorsal region from a severe trauma at the age of 3 Although there was complete paralysis of the lower limbs, their normal growth had not been materially altered They conclude that the sympathetic nervous system must largely control growth and regeneration of tissues and that this case offers a strong argument against the existence of trophic cerebrospinal centers

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46 Clark L P New York M J **115** 131 (Feb 1) 1922

47 Cadwalader W B Am J M Sc **162** 872 (Dec) 1921

48 Lhermitte and Pagniez Presse med **30** 57 (Dec 21) 1922

## ARTHRITIS

*Chronic Infectious Arthritis*—Billings, Coleman and Hibbs<sup>49</sup> have studied the end-results of treatment of 411 cases of chronic arthritis. They consider that their investigation confirms the view held by a majority of clinicians that chronic deforming arthritis is primarily an infectious disease and that the micro-organisms which are most commonly responsible are strains of nonhemolytic streptococci of relatively low virulence, and less often strains of nonpyogenic gonococci and other bacteria of low pathogenicity. In 50 per cent of their cases, the tonsils seemed to be the probable foci of infection, and the embolic mode of infection caused the tissue reactions, proliferative, hypertrophic, atrophic or degenerative. General chronic infectious myositis with only slight joint involvement in the early stage of the disease was a clinical entity in the group studied. The more acute the onset, the more favorable the prognosis proved to be. Of a group of 133 patients admitted within two years after the onset, 31.5 per cent recovered and 27 per cent were improved. Of 278, whose disease started more than two years before admission, only 10.4 per cent recovered and 38.1 per cent were improved. Of 229 patients who received vaccines, 17 per cent recovered and 38.9 per cent improved. Of 164 who did not receive vaccines, 17 per cent also recovered and 28 per cent improved. They consider treatment by vaccines to be of little value. Of 186 patients who carried out physical therapy thoroughly, 32 per cent recovered and 61 per cent improved. The authors are convinced of the importance of the avoidance of fatigue, and also of the value of daily physical exercise and hydrotherapy.

[ED NOTE—Such an extensive review by eminent internists of cases of this baffling disease is of great value. It makes it evident that we as yet have no rapid method of cure in the majority of cases and that we must always first search for a surgical focus. It is also clear that the finding of a probable focus and its eradication may not, unaided by other methods of therapy, result in a rapid cure of the disease or even, in many instances, in a satisfactory improvement. The lines along which this improvement and eventual cure must apparently be sought are, as the authors suggest, general physiotherapeutic lines, heliotherapy, massage and exercise. We are convinced that the absorptive and eliminative functions of the intestinal canal are from the start intimately connected with the solution of the problem and that therefore, the question of diet is of great importance. Painstaking studies of diet and blood gases along biochemical lines which have been made and are being made by Pemberton and others have helped and we

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<sup>49</sup> Billings, F., Coleman, G. H. and Hibbs, W. G. Chronic Infectious Arthritis. *I. A. M. A.* 78: 1097 (April 15) 1922.

believe, will continue to help, toward the solution. It is also evident that the attempts of Goldthwait, Swaim and others to improve the bodily mechanics of these chronic sufferers have been attended with much success in restoring function and apparently arresting the course of the disease. We will call attention here to a review of Dr Percy Wilde's book, which concludes this section, advancing a different theory for the cause of chronic arthritis. The report of a personal observation of Wilde's work and results indicates that more attention should be paid to his theories and methods than they have received in this country.]

*Autoserotherapy in Arthritis*—Dufour, Thiers and Alexewsky<sup>50</sup> add three new cases to their previously reported three, in which what they consider as rapid cures of arthritis have resulted from subcutaneous injections of fluid obtained by aspiration of an affected joint. They inject from 10 to 20 c.c., repeating this injection as often as aspiration is required. They have found the method harmless, even when the fluid contains pus or gonococci. Their six patients have recovered in from four to thirty days, and in seven similar cases published by other authors, the results have been equally successful.

*Dental Foci*—Lurie<sup>51</sup> emphasizes the importance of not being satisfied with mere tooth extraction in the attempt to remove possible foci at the roots of the teeth. A granuloma, a cyst or an apical abscess may be left behind. He advises opening the alveolus under local anesthesia and dissecting out the root, really removing the surrounding source of infection. He reports two cases of sciatica relieved in two or three days after such complete removal of dental foci. One of these cases was of four weeks' and the other of six weeks' duration. Salicylates, medical baths, and a belt had failed to relieve, and one of the patients had had simple extraction of the teeth previously without benefit.

#### BOOK REVIEW

THE PHYSIOLOGY OF GOUT, RHEUMATISM AND ARTHRITIS  
AS A GUIDE TO ACCURATE DIAGNOSIS AND EFFICIENT  
TREATMENT. By Percy Wilde. Cloth, \$3.50. Pp. 229, with 31 illustrations. New York: William Wood & Co., 1922.

The author's enthusiasm for his subject is infectious and his presentation admirable. He believes that arthritis is not a definite disease, but an expression of faulty physiology. His experiments have convinced him that certain of the chemical techniques previously employed have been faulty, and that, for instance, in estimating the quantity of uric acid, the only nitrogenous product in the solution has been added by the chemist himself in the course of his experiment. He holds that the production and elimination of lactic acid and the so-called lactic acid diathesis are of great importance. The application

<sup>50</sup> Dufour, Thiers and Alexewsky. Bull. et mem. Soc. med. d. hop. de Paris 45: 1558 (Nov. 25) 1921.

<sup>51</sup> Lurie, W. A. New Orleans M. & S. J. 74: 622 (March) 1922.

of physiologic theories to the treatment of the various forms of rheumatism and gout is most interesting and suggestive. If he rides his hobby a bit hard and perhaps attempts to explain too many conditions, it is none the less the hobby of a very observant man who has not been satisfied with the long established methods of investigation and treatment and has attempted to work out a more rational physiology.

*Simultaneous Hydrops of the Knees*—Under the title "Simultaneous Hydrops of the Knees," Fitz-Simmons<sup>52</sup> discusses thirteen cases of bilateral knee joint effusion observed at the Children's Hospital, Boston. After a careful study of these cases, the etiologic factor was discovered to be tuberculosis in four, positively syphilitic in four, and an infection, neither tuberculous nor syphilitic, in two. In the tuberculous joints, pain was an earlier and more constant symptom. Fever was more common and the constitutional symptoms of general weakness and tire were more marked than in the syphilitic group. Surface temperature, bony thickening, limitation of motion and a more rapidly destructive process were more characteristic of the tuberculous joints than of the syphilitic. Symmetrical synovitis of the knee joints in a child, chronic in nature, free from marked symptoms of pain even on motion, strongly suggests hereditary syphilis. In these joints, an excellent functional result may be expected.

*Injection of Ether in Chronic Hydrarthrosis*—Rocher<sup>53</sup> has practiced, for more than a year, injection of sulphuric ether into joints affected with chronic hydrarthrosis, presumably of unknown etiology. The injected ether is squeezed into all parts of the synovial cavity, which should be under slight tension from the injected fluid. The fluid is then quickly withdrawn. A compression bandage is applied. There is moderate pain followed by anesthesia, but some pain and swelling persist for twenty-four hours. He reports a case of four years' duration relieved in five days.

*Intermittent Hydrops*—Nielson<sup>54</sup> reports a fairly typical case of irregular intermittent hydrops, on which two arthrotomies were performed with no permanent relief, the attacks later on occurring regularly, from every ten to eleven days.

[ED. NOTE—This experience is in keeping with that of the Editors. In the cases observed by them, improvement of posture, foot strain and general bodily mechanics have in several instances been associated with a lessened frequency and severity of the attacks, and in one case therapeutic administration of roentgen rays, every three weeks for a

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52 Fitz-Simmons H. J. *J. Bone & Joint Surg.* 4:376 (April) 1922.

53 Rocher, H. L. *Presse med.* 30:256 (Feb. 15) 1922.

54 Nielson A. L. *Intermittent Hydrarthrosis*. *I. A. M. A.* 78:507 (Feb. 18) 1922.

period of two months, in addition to this correction of bodily mechanics, has been followed by a subsidence of attacks, which has lasted for six months and is still continuing ]

*Juvenile Deforming Osteochondritis of the Hip Joint, Pseudocoxalgia, Cora Plana, Legg, Calvé, Perthes Disease*—Lance,<sup>55</sup> reporting seventeen cases of this condition, has been impressed with the fact that an hereditary history could be established in many of the cases. He believes that other infections may be responsible, but that, in the syphilitic cases, medication has materially modified the disease, a complete restitution having been realized in some of the cases.

Platt<sup>56</sup> has written a thesis under the title "Pseudocoxalgia" which very completely covers the subject. His conclusions, based on the close observation of a large number of cases, are as follows: (1) Pseudocoxalgia, or osteochondritis deformans juvenilis, is a definite entity, representing the reaction of the metaphyseal region of the upper end of the femur to the stimulus of an infective agent of attenuated virulence. (2) The condition is comparable to arthritis deformans juvenilis coxae, which is seen solely in adolescents and represents at this age the reaction of the hip joint to an infective agent of similar type. (3) In the conditions known as tarsal scaphoiditis (Köhler's disease), apophysitis of the tibial tubercle (Osgood-Schlatter's disease), bony changes parallel to those in pseudocoxalgia are found. (4) Conservative treatment directed toward the elimination of weight bearing has no proved influence on the train of morbid symptoms, but its application is indicated during the stage of prominent symptoms. Operative treatment directed toward the removal of the dominant lesion has no place in the therapy of the disease at present.

#### NEOPLASMS

*Cysts in Bone*—Mouchet and Le Gac<sup>57</sup> are convinced from a study of their cases that trauma plays an unimportant rôle in the etiology of simple bone cysts. Trauma, on the other hand, often results in a cure of the condition, allowing the fluid to escape, which is followed by periosteal repair. Immobilization in these cases is all that is required. When cysts of the large long bones are discovered, they should be trephined and curetted, but not filled or drained, since they are sterile and benign.

*Myioma of the Knee*—Bolognesi<sup>58</sup> reports a case of pure myioma occurring in a knee joint. The lesion resembled very closely a fungous type of tuberculosis.

<sup>55</sup> Lance. Andrieu and Capelle. *J. de chir.* 18: 471 (Nov.) 1921.

<sup>56</sup> Platt. *Brit. J. Surg.* 9: 366 (Jan.) 1922.

<sup>57</sup> Mouchet and Le Gac. *Arch. franco-belges de chir.* 25: 337 (Jan.) 1922.

<sup>58</sup> Bolognesi. *Chir. d'org. di movimento* 6: 17 (Feb.) 1922.

*Metastatic Carcinoma of Bone*—Catsaras<sup>59</sup> has found one case in the literature of metastatic carcinoma of bone from a primary focus in the liver. In a second case which he reports, the head and neck of the femur were invaded by an adenocarcinomatous metastasis from the liver, the tumor cells in the femur being deep green in color, with abundant production of bile.

Oppenheimer<sup>60</sup> has analyzed thirty-two cases of spinal cancer seen at the Montefiore Hospital in New York. The breasts were the primary seat in 66 per cent of the cases, the lung and thyroid being the next most common sources of origin. Three of the patients had had breast operation at least eight years previously without local recurrences. In seven of the cases, the first indication of the spinal lesion was fracture following slight trauma, pain having been absent before the fracture. In nineteen, however, pain had been a prominent symptom, and ten patients had pain on local pressure. In fifteen, pain in the lower extremities was present, and in thirteen this was an early symptom. Deformity was present in fourteen cases. The roentgenologic findings were positive in only fifteen cases. Fifteen patients had no symptoms referable to the central nervous system. The writer believes that it is possible to foretell the ultimate vertebral breakdown long before it occurs. The most typical change is slight dislocation forward, so that there appears a more or less definite recession of one or more spinous processes. Slight lateral displacements are also not uncommon.

*Sarcoma*—Valentin<sup>61</sup> adds one more to Stern's compilation of twenty cases of sarcoma of the os calcis. The symptoms dated back six or seven years, and histologic examination of the tissue, removed in a piecemeal extirpation, demonstrated it to be of the epulis type. Valentin considers cutaneous venous dilatation, with an otherwise normal skin, to be an important sign of neoplasm of the tarsus.

Meyerding<sup>62</sup> has made a study of 109 patients operated on at the Mayo Clinic, whose cases were proved to be sarcoma by pathologic examination. From 1907 to 1921, 470 cases were diagnosed as sarcoma of the extremities. Thirty-five per cent of these patients were considered to be inoperable or refused operation. Thirty-two of the thirty-five patients who underwent an amputation died subsequently. The average duration of the disease at the time of operation was seven and thirty-four hundredths months and the average length of life following the operation in those who died was fourteen and five-tenths months. The most malignant of the series were the osteosarcomas (probably

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59 Catsaras. *Ann de med* 10 295 (Oct.) 1921.

60 Oppenheimer, E. D. *J Bone & Joint Surg* 4 342 (April) 1922.

61 Valentin. *Klin Wchnschr* 1 24 (Jan 1) 1922.

62 Meyerding, H. W. *Surg, Gynec & Obst* 34 321 (March) 1922.



the osteogenic type of Ewing, which will be reported later) Meyerding believes that if any doubt exists as to the nature of the tumor, an exploratory operation and a microscopic examination of the tissue are demanded before resorting to radical operation. The principal points to be determined before operation are the question of malignancy, the existence of metastases and the extent of bony involvement.

Ashhurst,<sup>63</sup> opening the discussion on sarcoma at the Philadelphia meeting of the American College of Surgeons, said that the pathogenesis of sarcoma must for the moment be left unsettled. In general, he urges the conservative treatment, and, in disagreement with Ewing (see next review), believes that excision of a portion of the tumor for microscopic examination is a harmless procedure and likely to save a life or limb. He considers that Coley's mixed toxins deserve a trial in all forms of bone sarcoma. The true value of radium has, in his opinion, not been determined.

Ewing<sup>64</sup> holds that a classification of bone tumors must not be made from the constituent cells they contain or from the possible origin of these cells. The classification must be both clinical and anatomic. The classification which he suggests is as follows:

Osteoma	{ Spongy Ivory		
Chondroma	{ Pure chondroma Chondromyxoma Myxoma	}	{ Capsular Periosteal Central
Angioma	Cavernous		
Endothelioma	{ Angio-endothelioma Diffuse	}	{ Solitary Multiple
Benign Central Giant-Cell Tumor and Its Variations	{ 1 Bone cyst 2 Giant-cell tumor 3 Xanthosarcoma 4 Myxosarcoma (benign)		
Osteogenic Sarcoma	{ Periosteal (extraperiosteal) Solid medullary and subperiosteal Telangiectatic Sclerosing		
Myeloma	{ Plasma cell Lymphocytic Myelocytic Erythroblastic		

In regard to prognosis and treatment of sarcomas of bone, he is very much opposed to diagnostic incisions as he believes that careful history, roentgen-ray findings, and the results of the therapeutic test with roentgen rays or radium are of much more value than the examination of a small isolated section of tissue which may not be in the right part of the tumor and which may go to a pathologist who is not

<sup>63</sup> Ashhurst, A. P. C. *Surg. Gynec. & Obst.* **34**: 333 (March) 1922.

<sup>64</sup> Ewing, James. *Review and Classification of Bone Sarcomas*, *Arch. Surg.* **4**: 485 (May) 1922.

conversant with bone tumors Ewing believes that the nonoperative treatment is the goal to be aimed at The vast majority of bone sarcomas of every type give highly characteristic roentgenograms, which, interpreted in the light of exact and simple clinical data, permit a reasonably accurate diagnosis Ewing lays emphasis on the following roentgenologic details Osteogenic sarcoma almost never affects the middle half of the shaft, but is a disease of the diaphyseal ends Erosion or destruction of a segment of the shaft is nearly constant in osteogenic sarcoma The benign central tumors regularly widen the shaft and displace the periosteum with its thin shell of bone, long before more aggressive forms of this disease invade the soft tissue Myelomas and diffuse endotheliomas involve wide segments of the bone, often the midportions, and cause smooth gradual fading of the shaft Syphilis, tuberculosis, chronic osteomyelitis and periostitis, Paget's disease, each presents its own peculiar morphology and clinical setting, and, with rare exceptions, lack the specific features of bone tumors But he goes on to say that the interpretations require experience

The therapeutic test is the decisive evidence between certain classes of bone tumors Myelomas and diffuse endotheliomas melt down rapidly under roentgen ray and radium These physical agents control the growth of the benign central tumors and cause the gradual restoration of the shaft, while the relief of pain is usually prompt With osteogenic sarcoma, roentgen ray and radium have little or no immediate effect on the size or form of the tumor Chondromas seem to be wholly unaffected by external irradiation

Ewing gives the following scheme to secure more accurate data regarding the prognosis of osteogenic sarcoma (1) encapsulated extra-periosteal fibrosarcoma fibrous, cartilaginous or osteoid stroma in excess of cells, prognosis, fair, (2) sclerosing medullary and periosteal sarcoma, course very slow, metastases appear very late, (3) cellular spindle cell periosteal sarcoma, stroma scanty or absent, some cures by surgery and other methods, (4) solid cellular central and sub-periosteal sarcoma, some surgical cures of early cases, (5) very vascular cellular telangiectatic sarcoma, no reported cures

Codman<sup>65</sup> explains the working and future plans of the Registry of Cases of Bone Sarcoma and asks the cooperation of all surgeons He discusses the nomenclature as used by the Registry, which is practically that of Ewing Osteogenic means derived from bone forming tissue and osteogenetic means a bone forming tissue Benign giant-cell tumors should be the term employed instead of giant-cell sarcoma The cases thus far registered fall into four groups (1) malignant osteogenic sarcoma, (2) benign giant-cell tumors, (3) rare forms of primary bone tumors (4) errors in diagnosis

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65 Codman, E. A. Surg., Gynec. & Obst. **34** 335 (March) 1922

The Registry has had correspondence concerning, or has actually observed, 454 cases. Of this number, it has been obliged to exclude, for lack of roentgen-ray examination, or lack of microscopic section and gross tissue, or because the diagnosis was obviously incorrect, 317 cases. There remained forty-one cases of osteogenic sarcoma, forty-three cases of giant-cell tumor and fifty-three cases were considered undetermined. In only five cases of osteogenic sarcoma are the patients known to be alive five years after the operation.

[ED NOTE—Codman and his associates have done much to awaken medical interest in this perplexing subject of bone sarcoma. The foregoing reviews will indicate how much there remains to be learned concerning this form of malignant and nonmalignant bone invasion. If American surgeons will cooperate, the Registry is sure to add to our knowledge and unify our terminology.]

#### OSTEOMYELITIS

*Acute Osteomyelitis*—Cohn<sup>66</sup> emphasizes the importance of early recognition of acute osteomyelitis if sequestration is to be prevented. He is convinced that it is a blood-borne disease, localized primarily in the medullary canal. There are no early roentgen-ray findings on which a diagnosis can be based, and the early operative findings may be only of fat necrosis of the medullary canal without frank pus. Early operation should give almost instant relief from pain, cause a subsidence of temperature, prevent the formation of sequestrums, and bring about a complete restoration of function. Cohn advises opening the medulla, preferably with motor driven instruments, even if pus is found beneath the periosteum, feeling sure that the infection has reached the cortex through the haversian system. The use of the curet is decried.

Starr,<sup>67</sup> in an article on acute hematogenous osteomyelitis, also considers the disease blood-borne from a focus situated elsewhere in the body. The disease occurs most frequently between 2 and 10 years. Trauma is a distinct factor, and boys are slightly more frequently affected than girls. Severe pain in the neighborhood of a joint with a spot of tenderness in a growing child is extremely significant. If this is accompanied by a high fever, rapid pulse and a high leukocyte count the diagnosis is fairly certain. The roentgen ray is of no assistance in early diagnosis and it is essential that an early diagnosis be made. The treatment should consist of an incision over the area of greatest tenderness, continued through the skin, subcutaneous tissue and periosteum. Care should be taken to keep the incision on the diaphyseal side of the epiphyseal line and to preserve the periosteal

<sup>66</sup> Cohn. New Orleans M & S J 74 505 (Jan) 1922

<sup>67</sup> Starr C L. Acute Hematogenous Osteomyelitis, Arch Surg 4 567 (May) 1922

attachment to the epiphyseal line, thus safeguarding, to a large extent, the danger of extension to the joint. If frank pus is encountered, Starr, in disagreement with Cohn, considers this incision sufficient a drain being inserted. If no gross pus is found, the periosteum is stripped for a short distance on either side of the incision, to make sure that the incision is in the right plane, and if no frank pus is seen, a series of drill holes, usually three, is made about one-fourth inch apart downward, toward, but not into, the epiphysis, extending into the center of the shaft. Starr says that in no case has he opened the medullary cavity. He considers it a dangerous procedure. When a case is seen in the later stages, efficient drainage should be established, but the definite operation is delayed until the sequestrum is separated. Then a channel is chiseled of sufficient size to allow the removal of the sequestrum through the involucrum. The cavity is cleaned of dirty granulation, sponged with iodine and packed tightly with iodoform gauze for forty-eight hours. After the packing and drains are removed, and if the remaining cavity is too large to fill easily with granulation, the edges are made saucer-shaped and the soft tissues and periosteum allowed to fall in and obliterate it.

[ED. NOTE—The difference between Starr's working rule and Cohn's is an essential difference. We take it Starr is discussing osteomyelitis in the immediate neighborhood of a joint. Cohn believes the cortex should always be drilled, whether frank pus is or is not encountered beneath the periosteum. Starr does not drill the bone if he finds gross pus beneath the periosteum. Starr's experience as child surgeon of the Sick Children's Hospital in Toronto has been a very long and broad one, and he follows his cases carefully. If he was obliged to open the shaft later in any considerable number of cases in which he encountered frank pus beneath the periosteum, or if the majority of these patients did not, in his opinion, do well, he would not give conservative advice. On the other hand, if in any case of osteomyelitis the infection was, in the early stage, limited to the exterior of the shaft and between it and the periosteum it would be most unwise, after having provided drainage at the seat of the infection, to drill into an uninfected shaft and perhaps carry the infection farther.]

*Epiphysitis of the Femur*—Dickson<sup>68</sup> lays especial stress on the importance of differentiating between tuberculosis and pseudocoalgia both of which have a slow onset, and pyogenic epiphysitis of the hip which has an acute onset, high fever and extreme pain. For the latter condition immediate operation is required which may well be only that of drainage as an initial procedure, a later operation when the

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68 Dickson, F. D. J. Missouri M. A. 19 16 (Jan.) 1922

child's general condition has improved, consisting of cleaning out of the necrotic material and instituting an attempt to sterilize the wound with surgical solution of chlorinated soda. Traction is maintained throughout the course of the treatment.

*Osteomyelitis from Colon Bacillus*—Satta<sup>69</sup> reports a case of putrefying, gangrenous osteomyelitis following a compound fracture of the leg. After five months, healing had occurred, but two months later, the leg again became swollen, and at operation a pure culture of colon bacillus was recovered from the pus.

*Growth Problems Following Osteomyelitis*—Speed<sup>70</sup> has been interested in the problems presented by a normal growth on one side and an impairment of growth, due to partial destruction of the epiphysis by an osteomyelitis, on the other. The epiphyses which unite last must be most carefully guarded. These are those, in general, away from the direction in which the nutrient arteries run. Thus the epiphyses of the knee, shoulder and wrist unite later than those of the hip, ankle and elbow. Unless a bony deformity is increasing very rapidly and interferes seriously with function or threatens skin necrosis, brace rather than operative procedures are favored for a year. In adolescents, if both clinical and roentgen-ray examination during the course of the year demonstrate marked disturbance of growth, Speed favors equalizing the length of the legs by resecting a portion of the normal companion bone. If the child is young, with many inches of growth expected, after two or three years, when it is quite positively established that the epiphysis of the damaged bone has ceased all growth and is destroyed, the author advises the excision of the epiphysis on the other side (epiphysectomy) to stop the overgrowth, each bone growing at an equal rate from the remaining epiphysis.

[ED. NOTE—We have had no experience with this method, epiphysectomy, for controlling growth and obviating marked differences in length in companion bones, one of which has been damaged in its growing center by an osteomyelitis. It seems to us to be a rather hazardous procedure. We should feel that any thorough destruction of a zone of growth might well interfere with the normal contour of the joint surface, if not at once, in subsequent years, and that an arthritis on the originally well side might be added to the child's locomotive difficulties.]

#### LOW BACK PAIN

*Fumculitis*—Sicard and Forestier<sup>71</sup> maintain that persistent low back pain from which tuberculosis, syphilis, gonorrhea, typhoid and

<sup>69</sup> Satta. *Chir. d. org. di movimento* 6:97 (Feb.) 1922.

<sup>70</sup> Speed Kellogg. *Surg., Gynec. & Obst.* 34:469 (April) 1922.

<sup>71</sup> Sicard L. A. and Forestier, J. *Presse med.* 30:45 (Jan. 18) 1922.

other infections can be excluded, is often caused by a funiculitis rather than a radiculitis. The seat of the trouble they believe to be in the funiculi. Removal of the appropriate laminae has relieved symptoms in their five cases, by opening up the intervertebral foramina.

*Anatomic Variation*—Leri<sup>72</sup> sounds a timely note of warning as to holding anomalies of the fifth lumbar vertebra responsible for low back pain. He points out the very frequent occurrence of these variations from the normal, in patients free from all symptoms and urges very careful elimination of other possible causes of pain before ascribing it to enlarged transverse processes and partial or complete sacralizations of the fifth lumbar vertebra. Finding a sacralization is not making a diagnosis.

O'Reilly<sup>73</sup> also calls attention to the common occurrence of these variations from the absolute norm. He thinks that marked variations represent inherent weakness and aggravate and prolong symptoms when spines presenting such abnormalities are subjected to strain.

Holland,<sup>74</sup> writing on the same subject, reports ten cases, three of which were in children under 11 years of age. In a child of 2½, the lateral masses of the sacrum are seen to be developing from two bone centers.

O'Ferrall,<sup>75</sup> after reviewing forty cases of low back pain from the Orthopedic Clinic of the Touro Infirmary, concludes that the symptoms are usually due to sprains or infectious arthritis of the lumbosacral joints. In his series, there were twenty-two cases of sudden onset, suggesting a true sprain, while eighteen had an insidious onset and in his opinion were due to infections. He has been impressed with the importance of searching for remote foci by making a very complete physical examination. He considers that venereal infection, especially syphilis, is a frequent etiologic factor.

Kuth<sup>76</sup> has analyzed 208 cases of low back pain occurring in 136 males and 72 females. Of 180 patients, eighty had had previous attacks. In seventy-five, trauma was a possible cause. Unfavorable static conditions in the spine or lower extremities, occupational strain operate as a direct cause to produce and prolong symptoms. The best results in relieving these symptoms were obtained when these static abnormalities were corrected, together with graduated systematic exercises.

[ED. NOTE—It seems to the Editors that Kuth has laid stress on a most important feature of these cases of persistent low back pain.

72 Leri. *Presse med.* 30 158 (Feb. 22) 1922.

73 O'Reilly. *Southern M. J.* 15 217 (March) 1922.

74 Holland C. T. *J. Bone & Joint Surg.* 4 215 (April) 1922.

75 O'Ferrall J. T. *J. Bone & Joint Surg.* 4 384 (April) 1922.

76 Kuth J. R. *J. Bone & Joint Surg.* 4 357 (April) 1922.

We agree in a general way with O'Reilly that marked anatomic variations and fifth lumbar partial or complete sacralizations represent potential weakness. We know that adventitious bursae often exist with enlarged fifth lumbar transverse processes. However, these abnormalities have been present often during many years of active life and have not caused symptoms. Then, as a result of fatigue or strain, faulty statics and poor postures become habitual, and the anatomic variation becomes, in combination with the wrong bodily mechanics, a source of irritation and pain. Certain it is that relief may be obtained by the correction of these postural defects by means of temporary supports and persistent exercises looking to the establishment of a muscle tonus which shall maintain correct attitudes of rest and activity. Surgery should be the last and, we believe, the rare resort. Removal of a supposedly offending transverse process is a serious major operation, and, by restoring correct statics, we may expect, in the absence of articular disease, to escape the necessity of ankylosing operations on the lumbar spine or sacro-iliac joints, valuable as these procedures in the occasional case may be.]

#### SCOLIOSIS

Lionti<sup>77</sup> calls attention to a form of scoliosis due to the ptosis of one kidney. Dieulafé, Bagozzi and Bender have reported cases and Girolamo adds one of his own. The scoliosis is, in its early stages, purely functional and has disappeared in three of the cases after nephropexy, the fourth patient refused operation. The concavity of the curve may be on the same side as, or on the opposite side from, the ptosed kidney.

*Operative Treatment of Scoliosis*—Sauerbruch<sup>78</sup> considers that the results he has obtained from operative procedures on the ribs in two cases of severe structural scoliosis warrant the hope that more complete correction can be obtained by operative than by nonoperative treatment alone. He has noted that in fibroid phthisis there is always a deflection of the spinal column toward the normal side. Following paravertebral resection of the ribs, the column bends slowly back, and, in certain cases, an overcorrection has occurred. With Lange he operated on a patient with high grade fixed scoliosis. Their plan was to resect a portion of all the ribs on the concave side. The operation was performed in two stages. At the first operation, the three lower ribs were attacked, because these deep-lying structures are the most difficult to reach beneath the muscles. No appreciable improvement occurred under gymnastics. Three months later, the first seven ribs

<sup>77</sup> Lionti. *Riforma med* 38 199 (Feb 27) 1922

<sup>78</sup> Sauerbruch. *Arch i klin Chir* 118 550 (Nov 24) 1921

were resected, from 4 to 5 cm being removed. No immediate improvement occurred, but, under gymnastic exercises, the body was gradually drawn over from the right convex to the left concave side and the patient became able to assume an erect position.

To offset the effect of the approximation of the ribs on the concave side, Frey, Sauerbruch's assistant, proposed the expedient of gathering together the widely separated ribs on the convex side. His experiments on animals seemed to demonstrate that such a procedure was effective (seen next review of Frey's article), especially when a portion of the ribs on the concave side had been resected previously. Sauerbruch employed this method in the case of an 18 year old girl, first resecting all the ribs on the concave side and then drawing the third, fourth, fifth, sixth, and seventh ribs closely together on the convex side by means of copper wire. He says that at the time the first dressing was removed the result was most surprising: the spine might have been called straight. Unfortunately, the wires cut through the ribs and were expelled.

Acting on a second proposal of Frey, Sauerbruch operated on a 17 year old boy in two stages. At the first operation, a 3 cm section was resected from the second to the ninth ribs on the concave side. At the second operation, a similar section was removed from the second to the eighth ribs on the convex side. A plaster cast was then applied in extension, with slight pressure on the scoliotic convexity of the chest. Eight days after the removal of the cast, the scoliotic convexity of the chest had nearly disappeared, and the curvature of the spine was considerably less.

Frey<sup>79</sup> reports his experiments on dogs and guinea-pigs of tying together several ribs on one side. This induced a scoliosis, which was more pronounced if the ribs on the other side were severed. In cadavers also section of the ribs on one side and close approximation of the ribs on the other side produced a scoliosis, the degree of which depended on the elasticity of the subject's spine. From these experiments, Frey argued that in cases of structural scoliosis, tying the ribs together on the convex side would tend to correct the deformity, and that resection of a portion of the ribs on the concave side would make correction more rapid and complete. He reports the partially successful accomplishment of this result in Sauerbruch's second case, to which reference has been made above. He admits that with much fixed rotation the spine must be first mobilized. He believes this may be accomplished by dividing the ribs on the concave side close to the spine and the corresponding ribs on the convex side at a distance from the spine after which a correcting cast is applied with head extension.



The ribs regenerate very rapidly, and he reports that the correction thus obtained in two old and extreme cases in boys of 16 and 17 was soon apparently permanently stabilized

[ED NOTE—These major operative procedures of Sauerbruch and Frey are certainly daring and based on suggestive experimental work. They recall the similar and partially successful work of Hoke<sup>80</sup> with a single case, which work we believe he never cared again to undertake. It is true the experience of the war has widened the field of thoracic surgery, and it may be that these extensive rib sections and resections will be found safe in less skilful hands than those of this eminent German surgeon. There may also be devised safe methods of utilizing the procedures which Frey has discovered are capable of inducing a scoliosis, and by their reverse application these methods may succeed in correcting an existing scoliosis. More experimental work needs to be done, and the end-results of more cases must be reported by the originators of these methods before the importance of their contribution to the treatment of structural scoliosis can be estimated.]

Krukenberg<sup>81</sup> emphasizes the importance of the psoas muscles in the pathology of lateral curvature. He likens the spine to a ship's mast held by four ropes, two of them being represented by the erector spinae and two by the psoas muscles. He believes the function of the psoas muscles is not so much the flexion of the hips, as the support of the spine. In lumbar scoliosis, this function is disturbed, and the psoas on the concave side acts as a bowstring and its contraction tends to increase the deformity, while the psoas on the convex side becomes weakened and stretched. Krukenberg, therefore, divides the psoas tendon on the concave side through an incision in the groin, finding the approach easier here than at its insertion, where it is also intimately connected with the tendon of the iliacus, which he does not wish to divide. In several cases, he reports being able to lengthen the spine 10 cm, and he has obtained a marked improvement in the deformity. After the operation, the spine is stretched while the patient is under an anesthetic and a spica applied. The author has also succeeded in improving the curvature by changing the direction of pull of the external oblique muscle which he finds altered in shape and function in scoliosis. His technic is as follows. In a case of severe right lumbodorsal scoliosis, the aponeurosis of the left external oblique is divided through a pararectus incision, extending from the xiphoid cartilage to the inguinal ligament. A horizontal incision is next made following Douglas line. The upper portion of the muscle retracts, and the lower portion which overlaps the rectus, is fastened to its sheath

80 Hoke. *Am J Orthop Surg* November 1903

81 Krukenberg. *Ztschr f orthop Chir* 42 193, 1922

in such a way that the right half of the abdominal wall is drawn toward the left side. He reports very encouraging results in three cases and suggests that the operation may, in certain instances, be combined with the tenotomy of the psoas, to which reference has been made above. Krukenberg has observed no unfavorable result from this operation in lessening the resistance of the abdominal wall.

*Nonoperative Treatment of Scoliosis*—Klein<sup>82</sup> states that the aim of the Scoliosis Clinic of the Massachusetts General Hospital is "to improve the symmetry of the severe scoliotic, so that after the maximum amount of correction has been obtained the muscles may become, with proper training, adequate to compensate for the remaining deformity." The methods followed are first, carefully supervised exercises to mobilize the contracted muscles and ligaments and to acquire complete control over the respiratory muscles, the importance of which had been previously demonstrated by Bucholz. When this control is obtained and this mobilization accomplished, the patient is placed in the Abbott frame and a fenestrated corrective jacket is applied, the pelvic girdle being rotated on a shoulder girdle as a fixed point in a direction similar to that employed by Forbes. Felt padding is applied once a week between the posterior convexity of the ribs and the cast, and the cast itself changed when it is no longer effective, the series being interrupted by exercise periods and split or hinged casts. Klein is insistent on the avoidance of any considerable muscular atrophy, and his cases show that he is successful in his attempt. As soon as the maximum amount of correction by cast has been obtained, the patient resumes muscle strengthening exercises and is fitted with a light retaining brace, the essential feature of which is an accurately fitting pelvic base. The general condition of the patient is checked up by medical examination and is of chief concern throughout the course of treatment, which before the case is accepted, the patients agree to continue for at least two years.

#### BODILY MECHANICS

*Posture and Cervical Rib Syndrome*—Todd<sup>83</sup> reports an interesting personal experience tending to demonstrate that the cervical rib syndrome may be produced by posture alone. In 1913, he contracted the habit of sleeping with his right arm stretched out almost vertically and his hand under his head. His first symptoms were noticed in January, 1921 and consisted of tingling of the right index finger and thumb and finally paronychia and desquamation. In March 1921 the position of the arm in sleeping was changed, because the symptoms became

<sup>82</sup> Klein A. Treatment of Structural Scoliosis at the Massachusetts General Hospital. J. A. M. A. **78**:418 (Feb. 11) 1922.

<sup>83</sup> Todd T. W. Ann. Surg. **75**:105 (Jan.) 1922.

so marked as to interfere with the use of the hand and fingers. In two months, the symptoms had largely disappeared, and the fingers had almost returned to normal.

*Effect of Bodily Mechanics on the Health of Children*—Talbot<sup>84</sup> has become convinced of the association of faulty bodily mechanics and constipation, cyclic vomiting, recurrent attacks of so-called acidosis, fever and abdominal pain of unknown cause. Fatigue and bad posture go hand in hand and form a vicious circle which must be broken. He recommends that recumbency in the hyperextended position, lumbar spine flat, costal angle widened, and thorax lifted and stretched, be assumed by these patients for at least one-half hour after each meal, and if possible, for an hour after the noon meal. Postural exercise training he believes important also, and occasionally the application of a retentive brace under orthopedic supervision.

*Orthopedic Examination of One Thousand Three Hundred and Ninety-Three Yale Freshmen*—Cook<sup>85</sup> has made a statistical study of postural conditions in an entering college class. He is impressed, as Lee and Brown have been at Harvard, with the low percentage of normally poised students. In measuring postural scoliosis by a plumb line from the seventh cervical, which should normally coincide with the line of the buttocks, he found that only 49.7 per cent of the students showed no deviation. Only 3.5 per cent showed no rounding of the shoulders, and only 44.1 per cent stood with normal anterior posterior curves of the spine. In more than 50 per cent, the chest was to some extent flattened.

[ED. NOTE.—These figures certainly show, as do those of Lee and Brown and the examination of army recruits, that much needs to be done in the way of physical training of American youth from childhood through adolescence and early youth if we are to develop a race of greatest efficiency.]

*Position and Activity of the Diaphragm as Affected by Posture*—Adams and Pillsbury<sup>86</sup> have studied the position and activity of the diaphragm in different postures. They find that the diaphragm is highest in the prone position, intermediate in standing, and lowest in sitting. In these three positions, the diaphragmatic excursion is equal on both sides. With the body lying prone on the right side, the right dome is higher than the left and the excursion on the right is twice as great as on the left, with it lying prone on the left, conditions are reversed. The extreme excursion is 6 cm., and the position of the

<sup>84</sup> Talbot, F. B. *Southern M. J.* 15:171 (March) 1922.

<sup>85</sup> Cook, R. I. *I. Bone & Joint Surg.* 4:247 (April) 1922.

<sup>86</sup> Adams, R. D. and Pillsbury, H. C. *Arch. Int. Med.* 29:245 (Feb) 1922.

heart accompanying changes in the position of the diaphragm is subject to wide range. In lateral recumbency, the dependent lung is relaxed and its diaphragmatic ventilation is in excess of that of the upper lung.

*Orthostatic Albuminuria*—Willy Rieser and S. L. Rieser<sup>87</sup> have studied two cases of orthostatic albuminuria in women, aged 24 and 28, respectively. They were of the low blood pressure type, 106 and 118, systolic. Without corsets, the patients both developed an albuminuria, with corsets, no albuminuria existed. They conclude that there is no relation between lessened blood pressure in the upright position and albuminuria. They believe it to be due to a renal stasis caused by compression of the left renal vein in the arterial pincers made by the aorta and the mesenteric artery. These pincers become active when the kidney is thrust forward by a lordosis or the mesenteric artery is pulled to tautness by the tug of a ptotic mesocolon.

*Circulatory Disturbances in the Feet*—Geist<sup>88</sup> calls attention to the frequency of circulatory disturbances as a cause of "foot complaints." In his series of sixty-seven cases, twenty-three were cases of varicose veins, and forty-two of arterial disease, falling into four groups: (1) congenitally small arteries, (2) arterial spasm, (3) arteriosclerosis and (4) thrombo-angitis obliterans.

#### BONE AND JOINT SURGERY

*Recurrent Dislocation of Patella*—Drehmann<sup>89</sup> considers that every case of recurrent dislocation of the patella must be dealt with individually and that no one surgical procedure is appropriate for all cases. Thus, bone, muscular, tendon and capsular operation, or combination of these, may be advisable. He reports an excellent result from utilization of the gracilis. He exposes the lower portion of the tendon by a longitudinal incision, dividing the tendon at its insertion near the tibial tubercle. A second incision is made a little above the patella and the tendon pulled up underneath the skin, passed through a slit in the quadriceps expansion at the mesial edge of the patella and finally inserted into the mesial condyle of the femur.

*Tenodesis of the Quadriceps Tendon*—In cases of quadriceps paralysis in young subjects in which it was important not to disturb growth, Saxl<sup>90</sup> has been able sufficiently to stiffen the knee for weight bearing by a tenodesis of the quadriceps tendon. A longitudinal incision is

<sup>87</sup> Rieser, Willy and Rieser, S. L. Etiology of Orthostatic Albuminuria. *J. A. M. A.* 78: 644 (March 4) 1922.

<sup>88</sup> Geist, E. S. *Minnesota Med.* 5: 98 (Feb.) 1922.

<sup>89</sup> Drehmann. *Zentralbl. f. Chir.* 1921, p. 629.

<sup>90</sup> Saxl. *Ztschr. f. orthop. Chir.* 42: 138, 1921.

made over the center of the tendon, splitting the fascia. Two lateral incisions, one on each side of the tendon are then made, and the tendon lifted and its posterior portion scraped and freshened. The tendon is then displaced laterally and the periosteum beneath incised longitudinally in the midline and pushed back on either side, carrying with it some of the muscle fibers of the subcrureus. The underlying surface of the femur is freshened with a chisel, and the scraped under surface of the tendon placed in contact with it. The pushed back periosteum is then sutured to the edges of the tendon, and the vastus internus and externus are sutured together over the tendon. A plaster cast in extension is applied for three months, followed by a light extension apparatus for a few months longer. The slight spring in the joint allows a more elastic gait, and sufficient rigidity is eventually obtained to allow weight bearing without apparatus. He reports six cases.

*Lengthening of the Quadriceps Tendon*—Bennett,<sup>91</sup> in a previous paper, has called attention to the part which the quadriceps tendon plays in the loss of mobility of the knee joint, following fractures of the femur, etc. Bennett has performed his operation of lengthening the quadriceps tendon in twelve cases, in the last four of which motion of at least 90 per cent has been gained. The author makes the following comments: (1) Contraction of the quadriceps without adhesions will produce loss of function of the knee. (2) Contraction and adhesion between the muscles themselves, or between muscle and bone, will produce loss of flexion of the knee. (3) The capsular changes which offer obstruction to flexion before the tendon has been released yield easily after lengthening the tendon. (4) Contraction of the muscular tissue following long immobilization for inflammatory knee joint disease occurs, but, in the presence of a sensitive joint, it is unwise to operate. (5) Time is an important factor. A patient who has walked five years with 10 degrees of motion is a better operative subject than one who has walked only five months, though his range of motion may be three times as great. In the former case, the joint and muscle tissue are in good tone and regain their function more quickly following operation.

*Results of Tendon Transplantation in Irreparable Paralysis of the Radial Nerve*—Perthes<sup>92</sup> reports the end-results in forty-four cases of tendon transplantation at the wrist for musculospiral paralysis. His operation is performed as follows. Having separated the extensor tendons of the fingers from their muscles, including the extensor longus pollicis, he divides the powerful flexor carpi ulnaris at its insertion to the pisiform, and, leading it around the outer border of

91 Bennett G. E. *J Bone & Joint Surg* 4 279 (April) 1922

92 Perthes Klin Wchenschr 1 127 (Jan 15) 1922

the ulna, attaches all the finger extensors and the extensor longus pollicis to it. He then attaches the tendon of the flexor carpi radialis to the detached tendons of the abductor longus pollicis and extensor brevis pollicis at the outer border of the radial epiphysis. He expects the new function to be assumed in from three to nine weeks. He has succeeded in restoring almost complete power of opening the hand and extending the fingers. The hand can be lifted well above the horizontal plane. As a rule, the power of closing the fist powerfully is lessened. If heavy labor is necessary, in order to make possible a more powerful closure of the fist, he attaches the tendon of the short radial extensor to the lower end of the radius, while the wrist is held in slight dorsiflexion. He considers the transplantations, however, much more important than this tenodesis.

*Transplantation for Paralysis of the Opponens Pollicis*—Two methods of tendon transplantation in cases of paralysis of the opponens pollicis are said to have yielded excellent results. (1) By the method of Krukenberg<sup>93</sup> the radial portion of one of the flexor tendons of the middle finger is split off at the wrist, the transverse carpal ligament being nicked to make it possible to obtain a little more length of tendon. This slip is then drawn distally and pulled through a tunnel made to the base of the thumb, to which it is attached subperiosteally. The thumb is placed in the palm, and the middle finger extended, to remain for thirty days. The result of the operation is that the thumb can be opposed to the rest of the hand without closure of the fist. (2) The second method is that of Nicolaysen,<sup>94</sup> who for paralysis of the opponens and flexor brevis pollicis, transplants the abductor minimi digiti to the metacarpal bone of the thumb, which operation the author finds was first proposed by Huber. He reports an excellent functional result. In these cases there is frequently a subluxated or very relaxed joint between the first metacarpal and the trapezium, for which relaxation Spitzzy has performed an arthrodesis. Nicolaysen anticipated the possible necessity of this in his case but found the functional result satisfactory without it.

*Functional Prognosis of Tendon Injury of the Finger and Hand*—Lier,<sup>95</sup> from material studied in the Swiss Institution of Accident Insurance during 1919-1920, comprising 450 open and seven subcutaneous tendon injuries, considers the probable prognosis under various methods of treatment. He concludes that primary suture of open injuries of the extensor tendons is more successful than that of the flexors. Secondary suture is less successful in both groups. When

93 Krukenberg. *Ztschr. f. orthop. Chir.* **42** 178, 1921.

94 Nicolaysen. *Deutsch. Ztschr. f. Chir.* **168** 133 (Jan.) 1922.

95 Lier. *Arch. f. Orthop.* **19** 383, 1921.

the injury consists of a smooth, clean severance, the outlook is better. The prognosis is better when the injury occurs in the second and third decades of life. Wounds of the tendons in the neighborhood of the metacarpophalangeal joint were more favorable than injuries elsewhere. The chief cause of failure was the cicatrization of the tendon with the surrounding tissues. Return to work was a little quicker in extensor tendon injuries than in flexor injuries, from thirty-two to fifty-five days. With subcutaneous laceration of the extensor aponeurosis at the terminal phalanx, a common injury, the prognosis was not good and suture was found to yield better results than splinting.

[ED NOTE—The latter statement of Lier's in regard to the superiority of the operative over the nonoperative method of treatment in ruptures of the extensor aponeurosis at the terminal phalanx is in accordance with the prevailing surgical teaching. The Editors can only state that after a considerable experience with both the suture and the hyperextended splint treatment, they have been impressed with the success of the latter. Union and excellent motion and function have been attained, even as late as five weeks after the rupture, by splinting the finger for two weeks in an aluminum finger splint extending from the palm to beyond the tip of the finger, the terminal phalanx being hyperextended. The palmar portion of the splint is removed at the end of two weeks, and only the finger splinted for from two to three weeks longer. Finally the terminal phalangeal joint is protected by a band of adhesive plaster, 3 cm wide, for a few weeks more. It is often quite difficult to repair accurately a torn aponeurosis by suture, and the results of this method of splinting have been entirely satisfactory.]

*Arthroplasty Versus Fixation of Elbow*—Bean's<sup>96</sup> article is a general discussion of the question as to whether from anatomic, mental, social and occupational standpoints an arthroplasty of the elbow, yielding some degree of stable motion or an ankylosis at an occupationally appropriate angle of flexion, is the better functional result. He has observed the results of a good many arthroplastic operations on the elbow and looked up the reported results of others, and considers the results not so favorable as is the general impression. He concludes that the operation in the light of this uncertainty of result and the time necessary to bring it about, is to be advised in a very limited number of cases. He believes that the functional result even with a few degrees of stable motion, following an arthroplastic operation, has no advantage over ankylosis or an excision with a partially flail joint.

[ED NOTE—Our own observation of actual results leads us to agree in a very general way with Bean's conclusion. The elbow joint, however, because of its anatomic conformation and its freedom from

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96 Bean H C Boston M & S J 186 313 (March 9) 1922

weight bearing and great strain, is perhaps the most favorable joint in the body for arthroplastic operation, both as regards immediate result and its freedom from later painful arthritic changes. We believe the emphasis should be placed on the perfection of our technic in arthroplastic operations on this joint and on a careful selection of cases, avoiding perhaps patients performing heavy labor, rather than on the abandonment of the operation for the older methods of excision and ankylosis. The extremely favorable functional results which follow well conceived and executed arthroplastic operations on the elbow in carefully selected cases should lead us to continue our attempts to perfect our technic. We admit these favorable results are almost occasional at present, but we believe them to be most hopeful.]

*Operative Mobilization of Stiff Fingers*—Hesse<sup>97</sup> discusses the appropriate time for arthroplastic operation on ankylosed finger joints. He urges great conservatism and long waiting. Never should these operations be attempted until at least six weeks have passed after any inflammatory signs. Perthes' rule is three months. He has abandoned tourniquets since he has had two cases of radial paralysis following the use of an Esmarch. He performs the operation through two lateral incisions between the anterior and posterior digital vessels. He resects as little as possible of the joint surfaces, but enough to allow full flexion and extension, and he carefully excises the cicatricial capsule. The results are by no means always satisfactory, the cause being usually the adherence of the overlying tendons to the bone and cicatricial changes in the overlying skin.

In this connection, an article by Cotton and Sawyer<sup>98</sup> is interesting. They report eight cases of stiff fingers as a result of various injuries and of varying duration up to one hundred and twenty-six days. The most favorable results which they have obtained from twenty-four hour traction and distraction in the line of deformity, followed by gradual change of pull toward flexion or extension as the case demands, lead them to believe that this method is superior to others.

[ED. NOTE—We have commented in a previous Report of Progress on the ease with which this traction may be obtained by the employment of a forearm and palmar cockup plaster splint in which a circular or "banjo" shaped wire extending beyond the fingers has been incorporated. This wire loop can easily be bent to be in line with the deformity, and to it are attached the elastic traction strings extending from the adhesive or glued skin traction finger bands. This method was first devised by Danforth.]

97 Hesse Arch f klin Chir **119** 1 (Jan 27) 1922

98 Cotton, F J, and Sawyer, E J Boston M & S J **186** 183 (Feb 9) 1922



*Excision of Head of Femur in Hypertrophic Arthritis*—Platt,<sup>99</sup> after discussing the somewhat uncertain outcome of manipulation and arthrodesis of the hip joint in cases of painful degenerative or hypertrophic arthritis of the hip, reports gratifying results from a modified excision of the head of the bone. His operation consists in removing the overhanging mushroomlike portion of the head, leaving a considerable stump of the neck and a slightly expanded upper portion. His exposure is obtained by removing the great trochanter and attached muscles, and, after the stump of the head and neck have been carefully smoothed and covered with wax, he thrusts this into the acetabulum and reattaches the trochanter at a lower level on the femoral shaft.

[ED NOTE—The Editors are in agreement with Platt as to the frequency of unfavorable results which follow manipulation and attempted arthrodesis of the hip joint in this type of arthritis. We incline to the belief that this operation of Platt's, or even a more complete excision, is rather more likely to relieve pain than manipulation or attempted arthrodesis. We say attempted arthrodesis, because, except in comparatively early cases when the range of motion rarely seems to justify arthrodesis, the nature of the pathologic process makes firm bony ankylosis, in our experience, hard to obtain. The articular ends, often devoid of cartilage, are eburnated for some depth, and, beneath this firm bone, the cancellous structure is very fragile, with frequent large open spaces or cavities, as Ely's bone sections show. These changes, which are almost always present in a well advanced case, are not favorable to bony ankylosis. In a recently observed case in a stout elderly woman, on whom an operation of arthrodesis was attempted, the weakened atrophic neck fractured at the slight trauma of removing the overhanging hypertrophic bone of the head. No recourse but a formal excision remained, and, though the end-result cannot be stated, the shock of the operation was slight and the convalescence has been much less uncomfortable than that following an arthrodesis, since only temporary fixation was necessary. At the end of six weeks, the patient has less pain and more motion than before the operation and can bear almost her whole weight on her leg without discomfort, there is, of course, the expected amount of shortening.]

*Results of Arthroplasty*—Hohlbaum<sup>100</sup> reports from Payr's Clinic the results of arthroplastic operations on eighty-five knees, two hips and four ankles. The operations were performed between 1911 and 1921. In 78 per cent of the knees the results were "good", in 22 per cent poor with one death, in 55 per cent of the hips, the results were good, in 45 per cent, poor with one death. The results of all the

<sup>99</sup> Platt. *Brit M J* 1 672 (April 29) 1922.

<sup>100</sup> Hohlbaum. *Arch f klin Chir* 117 647 (Dec 24) 1921.

ankle operations were considered satisfactory. The best results were obtained in stiffened joints following Neisser infections and in those ankylosed by injuries. Metastatic infections were less favorable, because of the great disturbance of muscle function. The end-result of an arthroplastic operation is often not reached for one or two years.

Kalima<sup>101</sup> has made macroscopic and microscopic studies of eighteen specimens from arthroplastic operations performed by Payr. The material included fourteen knee joints, three hips and one elbow. The connection between the bone ends was cartilaginous and bony. There was no evidence of inflammatory processes in the bone ends. While the ligamentous apparatus were least altered macroscopically, the capsular ligament and periarticular tissue were markedly altered. The capsular portions, microscopically, were seen to have undergone most extensive fibrous and cicatricial transformations. These studies would seem to indicate the necessity for radical removal of the capsular and ligamentous tissue in performing arthroplastic operations.

*Results of Astragalectomy*—Armitage Whitman<sup>102</sup> has studied the end-results of sixty astragalectomies performed at the Hospital for the Ruptured and Crippled, about half by Dr. Royal Whitman and half by other surgeons. These operations were performed chiefly for paralytic calcaneus, but Armitage Whitman says that the usefulness of the operation has become so apparent that it is being employed for relief of paralytic valgus and varus, dangle foot and clubfoot. The results are best in the class of cases for which the operation was originally devised, talipes calcaneus. For varus and valgus deformities, it is a last resort, and the results are not so satisfactory. Especially likely to occur is a varus deformity if there is even a trace of power left in either the tibialis anticus or posticus. The common fault in operating is not to displace the foot far enough backward and anchor it there. Of the sixty cases examined, the results were considered satisfactory in fifty-one, or 85 per cent, eight were improved and one was a failure. Ninety per cent of the parents or the patients considered the operation a success.

*Extra-Articular Bone Bridging for Arthrodesis*—Muller<sup>103</sup> has attempted in dogs to produce a stiffening of the ankle joint by extra-articular bridges of bone transplanted into the tibia and calcaneus. The attempts were failures, for in time the transplant formed a pseudarthrosis opposite the line of the articulation. The same pseudarthrosis formed when the attempt was made to bridge the articulation by stimulating the formation of an exuberant callus.

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101 Kalima. Beitr. z. klin. Chir. **124** 423, 1921.

102 Whitman, Armitage. J. Bone & Joint Surg. **4** 266 (April) 1922.

103 Muller, Walther. Beitr. z. klin. Chir. **124** 315, 1921.

*Spontaneous Healing in Transplanted Bone*—Haas<sup>104</sup> transplanted freshly removed bones, which he fractured into muscle tissue and observed the healing of the fractures, though eventually the bone was absorbed. He concludes, therefore, that there is sufficient energy in the osteoblastic cells of a living bone transplant, even removed from all bony contact, to form a union between the fragments. He believes that these experiments clearly indicate the advisability of employing fresh living transplants for all purposes.

*Slipping Rib*—Four articles on "slipping rib" have appeared in recent issues of the *British Medical Journal* by Davies-Colley,<sup>105</sup> Marshall,<sup>106</sup> Mahon<sup>107</sup> and Ewart<sup>108</sup>. Abnormal mobility of the lower intercostal joints they consider fairly common and capable of producing very annoying symptoms. In Davies-Colley's two cases, excruciating pain was produced by exertion, the sharp stabbing character giving place to a dull ache. A mistaken diagnosis of deep abdominal or thoracic lesion had resulted, in one of his cases, in the performance of a futile laparotomy. The removal of 3 inches (7.6 cm.) of the terminal cartilage of the tenth rib effected a complete cure in both of his cases. In one of Mahon's cases, the ninth rib was affected and successfully healed in the same manner. Marshall reports the removal of a small portion, three-fourths inch (19 mm.) of the cartilage, of the third rib in one case, and of the end of the eleventh rib in another case, with relief of symptoms.

*Posttraumatic Spondylitis*—Kummell<sup>109</sup> has written a late article on the disease which bears his name. He maintains that it is quite distinct from the changes seen in a compression fracture which are evident in the roentgenogram immediately following the injury, while in the cases of posttraumatic spondylitis the early roentgenograms show no changes, and only those taken at a much later period show the collapse of the vertebral bodies and destruction of the intervertebral disks. He mentions three stages in the disease: (1) the stage of initial injury with an immediately following more or less severe shock, superseded in a short time by continued local pain in the region of the affected vertebrae, (2) a stage of relative well being and the resumption of activity, (3) after weeks, months or years, the formation of a knuckle and the recurrence of increasing pain. The treatment, in his opinion, consists of recumbency for several weeks. If the patient, as is usual, is seen in the third stage, he is given a brace which he wears for from four to

104 Haas S. L. *I Bone & Joint Surg* 4 209 (April) 1922

105 Davies-Colley *Brit M J* 1 432 (March 18) 1922

106 Marshall, Poynton and Soltau *Brit M J* 1 516 (April 1) 1922

107 Mahon R. B. *Brit M J* 1 602 (April 15) 1922

108 Ewart *Brit M J* 1 622 (April 15) 1922

109 Kummell *Arch t klin Chir* 118 876 (Nov. 24) 1921

six months and then abandons it if ankylosis is firm. He is inclined to favor an ankylosing operation on the spine as diminishing the period of convalescence and producing a more sure freedom from symptoms, especially in laborers.

*Flexion Contractures of the Knees*—Maragliano<sup>110</sup> reports two cases of persistent flexion contracture of the knees in which forcible straightening and long retention in plaster have been followed by a recurrence of the deformity. In these cases, he injected 60 per cent alcohol into the branches of the sciatic nerve supplying the semimembranosus, semitendinosus and the long head of the biceps. The result was an apparently permanent relief of the contracture.

*Isolated Disease of the Tarsal Scaphoid, Kohler's Disease*—Risser<sup>111</sup> has observed a case of this peculiar disease with a typical roentgenogram of a small dense scaphoid. Without any support, the acute symptoms disappeared in approximately three months, and in six months, it was impossible to distinguish any difference in the shape or structure of the two scaphoids in the roentgenograms.

*Diagnosis and Treatment of Common Injuries of the Shoulder Joint*—Lovett<sup>112</sup> points out the importance of recognizing the difference between sprains of the ligaments, muscular strains, injuries to the biceps tendon, rupture of the supraspinatus tendon, bursitis and synovitis in injuries of the shoulder joint. He advocates the use of the aeroplane or platform abduction splint in all cases. He believes that gradual abduction of the arm by means of such a splint is more efficacious and less painful in cases of adhesions than massage and nagging passive movements. Occasionally, manipulation under an anesthetic saves time. He considers that the saber cut incision of Jones and Codman offers the best approach for the repair of a ruptured supraspinatus tendon, and in cases in which a chronic subacromial bursitis has not yielded to treatment, or in which there is a calcareous deposit in the walls of the bursa.

[ED NOTE—We have called attention to the fact that under conservative treatment many of the patients in whom calcareous deposit in or about the bursa are evident in the roentgenograms not only are relieved of their symptoms, but also of their calcareous deposits, as far as the roentgen-ray evidence goes, by conservative treatment. We do not believe that the finding of these deposits, even of considerable degree, always indicates the necessity of operative removal. A very important factor in the production and relief of shoulder joint symptoms

110 Maragliano. *Chir. d. org. di movimento* 5:659 (Dec.) 1921.

111 Risser, A. S. *Isolated Disease of the Scaphoid Bone of the Foot*, *J. A. M. A.* 78:647 (March 4) 1922.

112 Lovett, R. W. *Surg., Gynec. & Obst.* 34:437 (April) 1922.

of the bursal type or the type spoken of by Lovett as irritable arm or false neuritis, occupational neurosis, etc., is, in our opinion, the habitual position in which the shoulder is held and used. It will be found, we believe, that most of these patients carry their shoulder far forward, and relief is often prompt and permanent if, by a light webbing elastic brace fastened to the corset or trousers, the shoulder is held well back in use, and the position is made habitual by appropriate exercises and correction of the general posture.

#### FRACTURES

*Fractures of the Forearm*—Magnuson<sup>113</sup> points out the fact that in fractures of the Colles and chauffeur type an injury to the distal radio-ulnar joint is a usual concomitant. Lack of recognition of this injury often leads to a limitation in supination. Fractures of one or both bones above the wrist should be fixed in the neutral position, or in full supination, since the space between the two bones is widest in these positions. In fractures proximal to the insertion of the pronator radii teres, Magnuson advocates open reduction because of the diverse muscle pulls, the likelihood of excessive hemorrhage due to injury of the nutrient artery and because of the greater danger of synostosis at this level. Fractures of the ulna proximal to the middle result from direct violence and are frequently associated with dislocation of the head of the radius, which should be examined. The author advocates bed treatment with traction in suspension as the best method, believing that many of the bad results may be attributed to the ambulatory method and lack of traction.

*Fracture-Dislocation of the Spine*—Hibbs<sup>114</sup> reviews twenty-two cases of fracture-dislocation of the spine, one in the cervical region, two in the dorsal, two in the dorsolumbar junction, and seventeen in the lumbar region. Eleven, or exactly 50 per cent of the whole series, were of the fifth lumbar vertebra. There had been a comparatively recent severe injury in all but five of the lumbar cases. These patients had received injuries often not thought severe in childhood, with symptoms not appearing until adult life. At operations performed on three of these five patients, ununited fractures of the pedicles or laminae were found. Hibbs believes that these late symptoms may be accounted for by the failure of the adult completely ossified vertebrae to accommodate for the bony abnormality. He advocates bony fusion as a means of relief of symptoms and reports success in every case of his series in which it has been performed.

<sup>113</sup> Magnuson, P. B. *Mechanics and Treatment of Fractures of the Forearm*. J. A. M. A. 78:789 (March 18) 1922.

<sup>114</sup> Hibbs, R. A. *Fracture-Dislocation of the Spine Treated by Fusion*. Arch. Surg. 4:598 (May) 1922.

*Kidney and Bladder Function Following Gunshot Fractures of the Spine*—Cumming<sup>115</sup> makes a further report of observations on the cases reported by Plaggemeyer on a series of twenty cases of shell fracture of the spine. Nine more cases are added. They have refrained from continued catheterization and employed urinary antiseptics, daily enemas and mild laxative. His conclusions are as follows: (1) Since the observations made by Plaggemeyer and in most of the shell fracture cases, since injury, there has been no return of the reflex nervous control of the bladder. From the neurologic standpoint, in general, there has been decided motor improvement and less, if any, sensory improvement. (2) In several cases, partial sex function is recorded. In one case, the man married and reports normal sexual power since the spring of 1920. His bladder picture returned to normal, and the only disability remaining is a slight sensory loss in the genitalia. (3) All except a few patients with shell fracture have recovered good general health, even though they may not have excellent kidney function. In the fatal cases, the patients died early in the course of the disease, in every instance from kidney infection and uremia. (4) In all except the one case noted above, we believe that the bladders have retained the changes developing subsequent to the injury. Each patient carries a small amount of residual urine. (5) In no case has there been infection late in the progress. Other complications have been avoided, owing to avoidance of catheterization as far as possible. (6) Of the two surviving patients who had had kidney infection, both came to operation, one for early drainage with complete recovery, and the other after more than a year for nephrectomy. (7) Use of the sinusoidal current for bladder stimulation was apparently efficacious for a time, but in two cases serious complications developed. (8) Of supreme importance to the patients themselves is the fact that their general condition has improved to a point at which they are ambulatory, enjoying life to a degree seemingly impossible. Their bladders have taken on the automatic state with which they can be entirely comfortable. (9) Hyperhidrosis, a constant finding in these cases, has persisted to a varying degree. All the trophic ulcers have healed. (10) Repeated cystoscopy in one case had no detrimental effect. Following nephrectomy for pyonephrosis of long standing, the patient improved and increase in kidney function occurred. (11) The average amount of residual urine found in the cases included in this report was 260 c c ( $8\frac{3}{4}$  ounces). Two patients had a constant residual amount of 80 c c (27 fluidounces), making the average relatively high.

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115 Cumming R. E. Shell Fracture of the Spine and Changes in Kidney and Bladder Function, J. A. M. A. 78:335 (Feb. 4) 1922.

*Fracture of the Pelvis*—Bacon<sup>116</sup> makes a report on thirty-two cases of fracture of the pelvis. The etiology is always direct violence, usually laterally applied, rather than anteroposteriorly. In this series, the pubic bone was fractured nineteen times, the ilium eighteen, and the ischium nine. Fractures of the ascending ramus of the ischium are the ones most commonly overlooked. Shock is nearly always present in pelvic fractures, and a slowly increasing ecchymosis in the pubic and perineal region is almost constant. Gross deformity is rare. The complications consist in tearing of the anterior and posterior ligaments of the sacro-iliac joints, which occurred in 25 per cent of the cases and was the most disabling feature, 25 per cent of the patients also sustained ruptures of the urethra and bladder, and half of these were fatal. Only one other case of the series resulted fatally. Nineteen of the thirty-two patients returned to their former work with an average disability of less than six months. In the treatment, he advises recumbency in a fracture bed, massage in three weeks, active and educative muscle movements in five or six weeks. He has discontinued the use of adhesive plaster strapping and plaster-of-Paris. The treatment of the shock is the most important. He believes that anatomic replacement in fractures of the ramus of the ischium, of the ramus and body of the pubic bone, or of the ilium near the acetabulum, is impossible by closed methods, and he advises against open operations.

*Fractures of the Neck of the Femur*—Dorrance and Murphy<sup>117</sup> have employed the abduction method in twenty cases of fracture of the neck of the femur, all but two occurring between the ages of 60 and 80 years. Of these twenty, they consider nine to have a good functional result, three walked with a slight limp, four walked with a cane. The two cases occurring in younger subjects, ages 37 and 50, obtained bony union. The roentgenogram in seventeen of the cases revealed dense fibrous union, though clinically firm osseous union seemed to exist. A point in reduction which they consider important is that before abduction is carried out, the assistant makes strong traction downward while the operator makes strong traction outward on the upper third of the femur, manipulating the fragments into position.

Henderson<sup>118</sup> also is convinced that bony union in fractures of the neck of the femur is difficult to obtain. He is of the opinion that the operations of Brackett and Whitman open a wide field for surgery, and if there is sufficient remaining neck and the patient is not too old, he believes that bone grafting and pegging have a place in the treatment.

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116 Bacon, J. E. *Southwestern Med* 6:4 (Jan.) 1922.

117 Dorrance, G. M. and Murphy, E. C. *Penn M J* 25:449 (April) 1922.

118 Henderson, M. S. *Penn M J* 25:452 (April) 1922.

*Metatarsophalangeal Fractures*—In Bolduc's<sup>119</sup> series of twenty-seven cases of these fractures, the commonest injury was a chip fracture of the terminal phalanx of the toes. He thinks that the treatment of the fracture is always surgical, to relieve tension of the extravasated blood in the sac about the encapsulated end of the phalanx. The Roentgen ray will reveal fractures in many cases of supposedly simple contusions.

*Nonunion of Fractures*—An excellent article on the nonunion of fractures has been written by Waring and Milligan,<sup>120</sup> which does not lend itself to abstract. The authors have not found it necessary to employ elaborate methods of bone grafting, plating or wiring. They do not hesitate to shorten the bones if firm union may be thus more certainly assured, feeling sure that functionally this is of first importance.

Putzu<sup>121</sup> divides the cases of nonunion of the bones of the upper extremity into three classes: (1) nonunion of short duration, with fragments in good position and no suggestion of interposition of soft tissues. The treatment consists of various methods of physiotherapy and stimulation. (2) Nonunion in which the fragments are in good position with little or no loss of substance, but separated by foreign bodies or soft tissue. The treatment consists of osteosynthesis by one method or another. (3) Nonunion in which there has been a considerable loss of substance or the bone ends have lost the osteogenic power of regeneration. Treatment is accomplished by means of bone transplants.

#### DISLOCATIONS

*Carpal Dislocation*—Speed<sup>122</sup> states that the cause of fracture dislocation of the carpal bones is always a fall on the hand. In fractures, immediate and prolonged immobilization is the only treatment likely to bring about union. If cases are neglected, nonunion and cavity formation result, and the excision of the whole bone is the procedure of choice. A dislocated carpal bone replaced very soon after the injury may renew its vascular connection and live. The compartment from which the bone escapes soon grows smaller and becomes filled with fibrous tissue, so that it becomes impossible to replace the bone or at least undesirable to do so, owing to the necessary damage to neighboring bones, while the dislocated bone, even if replaced, will probably lie in the wrist as an irritating foreign body.

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119 Bolduc, A. G. J. *Industrial Hygiene* 3: 371 (April) 1922.

120 Waring, H. J. and Milligan, E. T. C. *Brit. J. Surg.* 9: 408 (Jan.) 1922.

121 Putzu. *Polislinico* 28: 528 (Dec. 15) 1921.

122 Speed, Kellogg. *Carpal Bone Fracture Dislocation* abstr. *J. A. M. A.* 78: 303 (Jan. 28) 1922.



Cohen,<sup>123</sup> on the other hand, in reporting a case of anterior dislocation of the semilunar bone, and reviewing the literature, concludes that closed reduction is the method of choice and may succeed as late as three weeks after the injury. In over 50 per cent of the cases, dislocation of the semilunar bone is associated with lesions of the neighboring bones.

Cohen<sup>124</sup> also reports a case of dislocation of the pisiform bone associated with a partial slip of the distal radial epiphysis. A blow or muscular action may produce the lesion, which is very rare in spite of its exposed position. That it is so rarely dislocated is due to the fact that it has a certain amount of normal give or play and that its capsule is so strongly reinforced by extension from the internal annular ligaments and the insertion of the flexor carpi ulnaris. Cohen states that the disability resulting from the dislocation is slight and hardly warrants the procedure of suturing it back in place.

*Dislocation of the Hip*—Bosch<sup>125</sup> has studied four personally observed cases of central luxation of the hip joint, reviewing the literature of seventy-five others. The mechanism of the fracture is a violent force acting in the direction of the axis of the neck. If at the time of the application of the force, the thigh is held in abduction, outward rotation and flexion, the head is driven into the anterior superior compartment of the acetabulum. If the thigh is held in abduction, inward rotation and flexion, the fracture occurs in the anterior inferior quadrant. Force great enough to fracture the acetabulum usually fractures other portions of the pelvis. Examination through the rectum is often helpful in diagnosis. The best method of reducing the subluxation is by continuous upward traction, combined with lateral traction. Bosch considers this much safer than forceful attempts at quick reduction, even if it requires heavy weights and twenty-four hours. When the trochanteric position had returned to normal, he succeeded in one case in reconstructing the acetabulum by pressure through the rectum. He advocates early voluntary motion, but freedom from weight bearing for ten weeks at least. If the lesion is unrecognized, much disability may be expected.

Campbell<sup>126</sup> reports a case of traumatic dislocation of the hip into the perineum, with avulsion of the greater trochanter. Every effort at close reduction failing, an open reduction was accomplished, twelve days after the injury. A thick aponeurotic band and the insertion of the gluteals was wrapped around the neck and resisted reduction. In four months the result was extremely satisfactory.

123 Cohen. Med Rec **101** 656 (April 22) 1922.

124 Cohen. Ann Surg **75** 238 (Feb) 1922.

125 Bosch. Schweiz med Wchnschr **51** 1129 (Dec 8) 1921.

126 Campbell W C. Perineal Dislocation of the Hip, J A M A **78** 1115 (April 15) 1922.

*Subastragaloid External Dislocation* — Jones<sup>127</sup> emphasizes the seriousness of subastragaloid external dislocation, as shown by a study of the literature, and reports a case of his own, complicated by fracture of the neck of the astragalus. The mechanism of the lesion is strong pronation with eversion. Tenotomy of the Achilles tendon may facilitate reduction, permitting lateral replacement of the dislocated os calcis. Traction on the os calcis should be accompanied by strong supination of the forefoot. In compound fracture dislocations, necrosis of the astragalus seems to be prone to occur and an early astragalectomy should, in Jones' opinion, be considered.

#### AMPUTATIONS AND PROSTHESES

*The Carnes Arm* — Radike<sup>128</sup> states that in Germany there has been a widespread demand for the Carnes arm, following the publications and demonstrations of Dr. Max Cohn. He recognizes the fact that it is a complicated apparatus and requires much training and long practice to obtain the necessary skill in its use, but he considers that its mechanical principles and its practical usefulness make it and the Sauerbruch arm the best forms of prostheses.

*Cineplastic Amputations* — Ten Horn<sup>129</sup> estimates that in Germany there were between 2,500 and 3,000 amputations after the cineplastic methods of Sauerbruch. He reports a study of 403 cases, half of them three or more years after the operation. Eighty-three and five-tenths per cent expressed themselves as satisfied with the result and the prostheses, 74.1 per cent used the prostheses continually, 8.8 per cent irregularly, 8.7 per cent, only for cosmetic purposes, and 8.4 per cent, not at all. Ninety-five and five-tenths per cent were engaged in some occupation. Of the upper arm amputations, occupational ability was fully restored in 59.8 per cent, 24.7 per cent, almost fully, 10.3 per cent, about half, and 5.2 per cent, only slightly. With forearm amputations, the figures were about the same, though a little less favorable. Of the total number of upper limb amputations, approximately 80 per cent were able to resume fully or almost fully their former occupations.

Blencke<sup>130</sup> esteems the Sauerbruch method of amputation and his prosthesis very highly, but regrets that the results have not come up to the expectations in many instances, owing to the lack of firmness and muscle power in the canals and loops. This he believes is due to imperfectly executed operations and to the want of persistence and energy, on the part of patients, in exercises.

127 Jones, Ellis. *J. Bone & Joint Surg.* **4** 325 (April) 1922.

128 Radike. *Arch. f. orthop.* **19** 551, 1921.

129 Ten Horn. *München med. Wchnschr.* **69** 230 (Feb. 17) 1922.

130 Blencke. *München med. Wchnschr.* **69** 202 (Feb. 10) 1922.

*Methods of Obtaining Long Stump in Thigh Amputation*—Sauerbruch<sup>131</sup> devised and executed a daring and apparently successful operation designed to supply a longer thigh stump in cases of high amputation or disarticulation of the femur. This consists of fashioning long skin flaps from the thigh, excising for tumor or osteomyelitis the necessary portions of the femur, incising the lower leg down to the ankle joint and turning the lower leg completely back on the thigh, implanting the lower end of the tibia into the acetabulum or the femoral stump. The tuberosities of the tibia became the condyles of the femur, the abductors and adductors of the thigh were sutured to the periosteum of the tibia and the vessels were uninjured. The operation was performed on a child, and the result was a completely movable stump, capable of weight bearing and rich in soft parts.

*Obstinate Equinus of Foot Stumps*—Kortzeborn<sup>132</sup> calls attention to the frequent obstinate equinus which results in foot stumps, following exarticulation of the Chopart and Lisfranc types and in certain atypical amputations. The cause of this he states is the shrinking of the posterior capsule of the tibio astragaloid joint, which must be subperiosteally separated and the bones manipulated before a lengthening of the Achilles tendon will avail to correct the equinus and restore the bones to their normal position.

Wilson,<sup>133</sup> as a result of experience gained during the war, in the treatment of patients with amputations of the lower limb, has shown that it is possible to get such patients out of bed without crutches and actively bearing weight on peg legs or simple forms of artificial limbs at a period of two or three weeks after amputations. Early weight bearing is a great advantage to the patient because (a) it promotes healing of the wound by improving the circulation, and in cases with terminal localized osteomyelitis favors the separation and spontaneous discharge of sequestrums, (b) it hastens stump shrinkage and prevents muscle atrophy and the development of joint contractures, (c) it favorably influences the patient's morale, (d) it greatly shortens the period until the permanent artificial limb can be fitted, and reduces the need of frequent alterations to the socket and thereby greatly reduces expense to the patient. Provisional apparatus to secure early weight bearing may be made to best advantage of simple materials, in the use of which the surgeon is already skilled. With understanding of the advantages of early weight bearing in the treatment of amputations of the lower limb and of the little difficulty involved in its application, the method should be universally applied.

131 Sauerbruch. *Deutsch. Ztschr. f. Chir.* **169** 1 (Feb.) 1922.

132 Kortzeborn. *Arch. f. klin. Chir.* **117** 758 (Dec. 24) 1921.

133 Wilson, P. D. *J. Bone & Joint Surg.* **4** 224 (April) 1922.

## BOOK REVIEW

ARTIFICIAL LIMBS AND AMPUTATION STUMPS A PRACTICAL HANDBOOK By E Muirhead Little Philadelphia P Blakiston's Son & Co 1922

It is with great pleasure that we welcome this book which fills successfully a long existent gap in surgical literature. With the exception of a translated edition of Broca and Ducroquet's book on "Artificial Limbs" and another small book by Huggins on "Amputation Stumps," both of which are much less comprehensive, no authoritative work on this subject has been published in the English language since the war.

Mr Little, in his capacity of consultant to the Royal National Orthopaedic Hospital and to Queen Mary's Convalescent Auxiliary Hospital at Roehampton, has had a particularly rich experience in the prescription and fitting of artificial limbs since the beginning of the war. Through his hands have passed many thousands of cripples representing every variety of problem, and this book embodies in a clear and detailed way his large experience.

The major part of the book is devoted to a study of various types of artificial limbs, and, in addition, he presents a complete description with illustrations of the official prostheses used by the British Ministry of Pensions. The British government, with about 40,000 cases of major amputations, early began experiments to develop improved types of apparatus, and many of the models finally adopted are superior to those which had been developed by private initiative alone. In the United States, the number of war cripples was not sufficient to stimulate originality on the part of the manufacturers, the ordinary industrial field being so large and profitable. The result is that our limb builders, although the best in the world before the war, have lagged behind their British cousins.

Cooperation between surgeon and limb maker is necessary for progress. The war has shown that few medical men know anything about artificial limbs. Those who perform amputations must know the requirements of a good stump and the functional possibilities of amputation at different levels, and should be able to advise the patient as to the best type of apparatus for him to use and where to obtain it. It is to be hoped that this book will do much to remove the present medical weakness.

## MISCELLANEOUS

*Brachial Plexus Injuries*—Adson<sup>134</sup> has studied the gross pathology of brachial plexus injuries by subjecting cadavers to various types of trauma, from two to three hours after death. Dissections were then

134 Adson Surg., Gynec. & Obst. 34:351 (March) 1922

made, and the lesion of the plexus observed (1) When the pull on the arm is downward and outward, as in a sudden attempt to release the hand or lower arm by jerking it away, extreme force may be followed by complete elongated laceration distal to the nerve trunks in the three cords (2) In other types of trauma, the lesions of the nerves are situated in the vicinity of the intervertebral canal, proximal to the brachial trunks (3) The lesions may be very slight, consisting of lacerations of the fascia about the cervical ganglion and the cervical trunk, with or without avulsion of the ganglion (4) Patients with milder injuries may be expected to recover partially or completely, without surgical treatment Those with more severe injuries rarely recover, even with surgical treatment

*Radiotherapy in Syringomyelia*—Coyon, Lhermitte and Beaujard<sup>135</sup> report great improvement in the gliomatous form of syringomyelia from systematic roentgen-ray exposures to the upper spine In one case, after fifteen months' treatment consisting of exposures, every eight days, to the cervicodorsal region, the disease was apparently completely arrested In their other case, a young man who was on the point of becoming helpless had his wage earning capacity restored after about thirty exposures in two stages Thirteen years later, this patient died of pulmonary tuberculosis, and necropsy revealed a retrogression of the gliomas and an obliteration of the cavities in that part of the spine which had been exposed, while the gliomatous tendency in the unexposed portion had continued to progress slowly No injury to the meninges or the nervous elements could be found

*Progressive Muscular Atrophy*—Goldthwait<sup>136</sup> describes a suggestive case of a man of 33 who for eight months had been suffering from a progressive muscular weakness affecting the upper and lower limbs, for which there was no discoverable specific cause There had been some weakness of the knees and ankles, always exaggerated by use, for the last four to five years There was obvious atrophy of the muscles of the legs, and less noticeable atrophy of the arm muscles, but no paralysis There was some weakness of the abdominal muscles The reflexes were all diminished The chest was flat, the abdominal wall thin and relaxed, and a ptotic attitude was constant The treatment was planned along the lines of correction of the bad bodily mechanics in the hope of restoring a more normal physiologic balance He improved markedly and surprisingly rapidly A report, six and one half years later stated that he had remained in good condition and was able to do all the work that could be expected of an active business man

135 Coyon Lhermitte and Beaujard Bull et mem Soc med d hop de Paris 46 387 (March 3) 1922

136 Goldthwait Boston M & S J 186 559 (April 27) 1922

# ARCHIVES OF SURGERY

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## TRANSACTIONS OF THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

FIFTH ANNUAL MEETING, WASHINGTON, D C, APRIL 29, 1922

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# THE PRESENT AND FUTURE IN THORACIC SURGERY

SAMUEL ROBINSON, M D

SANTA BARBARA, CALIF

It behooves the president of a well-established medical society to address its members in person. Regrettably, I am compelled rather to write you a letter apologizing for my unavoidable absence and wishing you a successful meeting and a free exchange of ideas on the subject to which this association is devoted.

I have chosen as my subject the present and future of surgery of the thorax. Would that I might so contrast the thoracic surgery of today with that of years gone by that its present status would be regarded as a blessed boon to humanity. Would that I might demonstrate that, as a result of persistent and untiring experimentation and clinical study, innumerable human beings are saved today who previously would have died. It would be a tremendous exhilaration to compile a list of modern operations which today might be combating pathologic conditions of the thorax with a success which our predecessors could not have conceived.

But alas, would the surgeon of fifty years ago look now with any degree of envy at the accomplishments of today?

The farmer may well console his mortification over the deficit from the crops of a dry year by picturing the harvests to follow the promised rains of the year to come, so, likewise, may we disguise our inadequacies in the thoracic surgery of today by dwelling on the possibilities of the future.

But for the present, let us face the present—not in the reflected light of future possibilities, but rather in the light of the actual improvement over the past.

Before the beginning of this century, a reluctance prevailed to enter the thoracic cavity for purposes other than drainage of fluids. Animal experimentation has since developed apparatus which has rendered an exploratory operation on the animal thorax a safe procedure. The danger of pneumothorax in wide operations on the human thorax has likewise been dispelled. Now, therefore, there need be no reluctance to enter the pleural cavity—at least not because of the region as such. This would seem to mark a great transition—a millenium. And some day, well it may, but since the development of differential pressure apparatus, has surgery of the thorax developed in anything like the

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\* Read before the American Association for Thoracic Surgery, Washington, D C April 29 1922



expected proportions? Many wide open operations were successfully performed during the war, but most of them were performed without differential pressure. Let us define the actual progress creditable to this discovery. The transthoracic approach to the esophagus, otherwise impossible, is now safeguarded by the use of apparatus. If the technical difficulties of such operation are overcome, the ultimate success may be credited to the discovery of differential pressure and to the development of a perfected technic during the present period.

Operations for mediastinal tumors, for tumors of the chest wall, for bronchiectasis, for lung tumors should be performed with the aid of differential pressure, even though they may be successfully executed without such accessories. We may justly assert that such operations are now more willingly undertaken because of the safeguard provided by apparatus, furthermore, that the mortality in such operations is probably reduced in that group in which apparatus has been used. Even this claim could not be statistically proved. Until such time as we are able successfully to perform an intrathoracic operation with differential pressure which could not be performed without it, or until we can definitely prove that the mortality from such operations as may be performed with or without apparatus is lower with than without, we cannot claim actual progress.

In considering the various surgical diseases of the thorax in turn, where is progress revealed and where is it lacking?

#### EMPHYEMA

I have recently reviewed this subject to date. The publications are legion. A large proportion of patients with acute postpneumonic emphyema will recover in a short time following the single open drainage employed for centuries. There is no definite evidence that any new drainage device, suction device, irrigation technic or any other invention has lowered the mortality or reduced the chronicity in these uncomplicated acute cases. This is perhaps an extraordinary statement, but, I, nevertheless, defy any one to corral statistics from all available sources including his own, which will prove the contrary.

One definite fact has been learned, that wide open drainage cannot and must not be instituted in the early stages of an acute hemolytic streptococcus emphyema. The danger of a superposed operative pneumothorax in these cases is established. When, however, the pneumonic pressure has subsided, there is ample evidence that open drainage is tolerated as well as in the ordinary acute pneumococcus emphyema. So likewise, is a closed technic entirely proper in the hemolytic cases from the beginning to the end, if you please. But after weighing the advantages and disadvantages of the open and closed method of handling acute emphyema one cannot be accused of senility or bad surgery who reverts to the old pre-war technic.

Nevertheless, it would be ridiculous not to concede that the development of the closed method of treating acute empyema expresses a definite contribution

The use of surgical solution of chlorinated soda (Carrel-Dakin solution), or other antiseptic, appears to me to be of great significance in the handling of cases of chronic empyema. Even though a closed method treatment of chronic empyema may frequently be inadequate to cure without a subsequent plastic operation, such an operation when performed is bound to be less extreme and less mutilating, and, consequently, less often fatal. The obliterative thickening of chronic empyema cavity walls under the cleansing and stimulating effect of Carrel-Dakin solution is unquestionably hastened. Cavities which would necessitate for their obliteration an elaborate, destructive operation of the Schede type may first be reduced in their proportions by antiseptic installation and irrigation applied by the closed technic, until, finally, if complete closure is not promising, a far less extreme plastic operation is sufficient to complete the cure. The best treatment of chronic empyema today is an intelligent combination of the antiseptic and operative treatments. Not infrequently, the operative portion of treatment should be first, in order to render a cavity in all its ramifications readily accessible to the irrigating solutions. In such instances, ribs and thickened pleura are excised not for the purpose of permitting caving in of the cavity, but rather of unroofing the cavity for inspection. The skin and muscle are then sutured in and over, a direct and unobstructed channel being left for the introduction of a tube or tubes to the remotest parts of the space to be sterilized and obliterated by closed treatment.

Should this association as such express its attitude regarding open and closed methods, Carrel-Dakin usage or omission, may we not denounce the establishment of two definite schools, one for, and one against, the closed treatment? The hyperenthusiast who has deceived himself sufficiently to believe that acute and chronic empyema are diseases always curable without any further surgical procedure than the introduction of a catheter or trocar is a menace to the community. So, likewise, is the pessimist, blind to the teachings of the day, who refuses to see any advantages in the closed method. He will occasionally openly drain and lose certain patients that would have been saved by closed treatment. He will perform extensive osteoplastic resections that might have been modified by Carrel treatment prior or subsequent, to his operation.

The scrupulous surgeon of today will train himself in the technic of both the closed conservative and the open radical methods of handling empyema. He will be equipped with suitable apparatus and instruments

for both. He will intelligently discriminate between the cases suitable for one method and those better adapted to the other.

#### BRONCHIECTASIS

It has always been my belief that the greatest triumph in thoracic surgery will be the surgical eradication of this deplorable disease. The enthusiast returns from the war who has often dragged a lung lobe into a spread thoracic wound, opened it, scraped it, washed it—yea, even removed it—and concluded, therefrom, that intrathoracic surgery is freed of its supposed dangers, and that the possibilities therein are comparable to those in the abdomen. Let him attempt the same performance in his home hospital in a case of lower lobe bronchiectasis. Then will he learn what real thoracic pathology means. The patient is placed on the operating table. The posture is uncomfortable. There may be cyanosis. It induces coughing. The anesthetist is greeted by an evacuation of a large amount of pungent, purulent sputum, incident to the posture on the table. The whole bronchial tree may be filled with this material as the anesthetist begins. If regional blocking and paravertebral procainization is carried out, the pleura is no sooner opened and traction on the diaphragm commenced than the need of general anesthesia is obvious. As the secretions well toward the trachea, the cyanosis increases. The lower lobe obstinately resists being delivered, the pleural adhesions are strong and widespread, the attachments to the diaphragm are ropelike and tenacious. Finger dissection is inadequate. Work with the knife and scissors is blind. Cleavages are sought in vain. The pericardium is dangerously involved in the adhesions. Meanwhile, the patient's condition may become distressing and perhaps alarming. If open pneumothorax is adding insult to injury, the lung cannot be used to plug the thoracic gap, because the lobe is not deliverable. If differential pressure is being employed, that too may be acting badly. The mucopurulent secretion may interfere with proper intratracheal air insufflation. It interferes with the respiration under positive pressure. There may be cyanosis, even with the head outside a negative pressure cabinet. And then the difficulties multiply. The complete liberating at one sitting may have to be abandoned. There is bleeding and infectious leakage from the lung, and bleeding from the diaphragm. Tight closure of the chest without drainage seems inadvisable under such conditions, and yet necessary to avoid the ills of postoperative pneumothorax. Suddenly, it is obviously time to return the patient to his bed. Not much has been accomplished.

I have related this story of a more or less typical operation for bronchiectasis to emphasize the difficulties which are facing us in lung surgery. And after all, the greatest dangers occur after the operation. It is the pathologic condition then developing which is likely to be

the patient's undoing. The pulmonary circulation is disorganized by the postoperative pneumothorax, closed or open, as the case may be. The respiratory apparatus is demoralized. The lung of the bad side is congested, following its traumatization. It is compressed by accumulated blood and fluid. Its better portions are incompletely filled because of restricted expansion. The diaphragm is fixed because its motions are painful, the chest wall is immobile for the same reason, and because of its constricting dressing, and the intrathoracic pressure has been so altered that lung expansion is further minimized.

Then come the dangers of pleural infection later in convalescence. There is more operating to be done. That person, then, with bronchiectasis who is fortunate enough to have disease in but one or two lobes, who withstands the severe primary operation and overcomes the subsequent derangements in his physiology sufficiently to withstand a second operation, and who meanwhile resists the infection incident to both, is, to say the least, fortunate. Nevertheless, we have obtained cures. Four years ago, the mortality was about 50 per cent. It is less now. Progress has been made and it will continue to be made. Let us labor persistently with the disease. The bronchoscope like the roentgen ray will help in the selection of suitable cases. Local therapy through the bronchoscope will perhaps abort the early cases. It will symptomatically relieve the inoperable cases, and it may cure those persisting areas of bronchiectasis which excisions have not included, or could not include. Radium or therapeutic roentgen ray may prove of value in conjunction with operation. We must further determine whether ligation of arteries or veins to a bronchiectatic lobe is of actual and permanent value, either as a cure or as a preliminary to lobectomy. I have mechanically produced bronchiectasis in dogs by ligating the main bronchus. The artificial bronchiectasis is devoid of the complicating elements resulting from infection as we see them in man, hence the excision of an artificially produced bronchiectatic lobe is not attended by the difficulties confronted in the human being. There is, nevertheless, an interesting field for animal experimentation.

There are other problems to be worked out in human bronchiectasis. Should a lobectomy be performed in one, two or three stages? Is there any advantage in delivering the infected lobe to the chest wall as a preliminary stage, disconnecting it subsequently by knife or cautery as the normal function of circulation and respiration becomes reestablished?

Can bronchiectasis be cured alone by arterial or venous ligation?

#### LUNG ABSCESS

Acute abscess of the lung continues to be a surgical disease curable by surgical drainage. I know of no specific improvement in technique. Methods of localization have improved. Certain plastic methods of

obliterating abscess cavities after drainage have been instituted. Some work has been done on the problems associated with the prevention and closure of bronchial fistulas, but nothing stands out conspicuously as an indication of progress. There remains a prevailing disinclination to diagnose these cases promptly and to attack them openly, but such are not the topics of this discussion.

Chronic lung abscess continues to baffle the surgeon. Drainage is of comparatively little value. I classify these cases with bronchiectasis, not that their pathology is by any means identical, but because excision is the type of surgical therapy which alone can combat such pathology.

#### TUMORS OF THE LUNG, PLEURA AND MEDIASTINUM

We must concede that little, if any, progress has been made in the surgical treatment of intrathoracic neoplasms, nevertheless one of the obstacles has been removed, namely, the danger of pneumothorax which is necessarily incident to wide intrathoracic exploration. The use of apparatus safeguards the transpleural approach to tumors, but pneumothorax is perhaps the least hindrance to success. Primary tumors of the pleura are diffuse. They may be extensive and yet they may not invade the lung. The excision of such tumors is obviously impossible unless they are recognized at their incipency, and such is clinically impossible. Primary tumor of the lung, on the contrary is a surgical possibility. Occasionally, an isolated growth within a single lobe of the lung is recognized by the roentgen ray. Its situation, unfortunately, is more likely to be central or near the hilum than peripheral. The mediastinal glands are involved early. Nevertheless, a lobectomy or even an excision of that particular portion of the lung involved is technically possible. Be that as it may, our results in lung excisions are thus far attended with such high mortality that one cannot conscientiously advocate a surgical therapy when the success in roentgenotherapy and radiotherapy are ever increasing. Although a lobectomy for neoplasm ought to be technically simpler than that for bronchiectasis, the roentgen ray and radium serve as an alternative treatment for the former but not for the latter.

The surgical removal of mediastinal tumors has not met any degree of success, nor can it be pretended that any particular progress has occurred in this field. A case is occasionally reported, but the successful outcome has not resulted from any new development of technic, apparatus or instrumentation, but rather from the favorable situation of the tumor from the lack of pleural involvement, and from the absence of metastasis. As to the future, I look rather to advance in roentgenotherapy than in surgical treatment. If the size of a mediastinal growth can be even so reduced by the roentgen ray that the usual distressing

symptoms are relieved, we are forced to substitute such treatment for a surgical attempt, the best attainment of which is likely only to be a partial removal of the growth

#### TUMORS OF THE CHEST WALL

In this group, we can claim not only recent progress but also great promise for the future. These tumors are generally of osseous or periosteal origin from the ribs. They are circumscribed, they generally encroach on the pleura without involving it. The skin is rarely involved consequently the thoracic wall defect, however extensive, may yet be covered by skin and subcutaneous tissue. To remove such tumors without opening the pleura necessitates a tedious dissection, associated ultimately with a pleural tear. This is one of the types of thoracic operation in which the virgin pleura is opened. There are no adhesions to prevent prompt collapse of the lung. If differential pressure is not employed, the operation is frequently interrupted by the onset of symptoms of wideopen pneumothorax. The pleural defect must be closed occasionally to restore normal breathing, this being done either by a gauze pad or by drawing the lung outside the body. Differential pressure in such cases averts these interruptions and obviates the dangers of wideopen pneumothorax, which, though rarely serious, are ever present in the operations outlined.

There is no evidence that the mortality in operations for excision of tumors of the chest wall has been lessened by the use of differential pressure. There is no evidence that these operations have been undertaken any more frequently because of this available safeguard. Frankly, then, if progress may be said to exist in this field, it cannot be credited to this developmental phase. Nevertheless, whatever may be the explanation, the surgery of the thoracic wall has experienced an advance. More and more patients will, from now on, be operated on, and, in the long run, it will be shown that the use of differential pressure in such cases is the indicated procedure.

#### TUBERCULOSIS

The surgery of pulmonary tuberculosis has advanced in the extrapleural field. Lung immobilization and collapse therapy are accomplished by various types of osteoplastic resections. Intrapleural procedures remain abandoned, essentially because the incipient processes which might be amenable to surgical excision are generally cured by hygiene and in those cases in which advance has occurred the process is too diffuse to be eradicated by surgical methods. The drainage of tuberculous cavities remains obsolete and there appears to be no prospect of a renewal of such therapy.

Just why the progress in the chest wall caving-in operation is yet tardy, it is difficult to explain. The number of so-called cases and the many instances of great symptomatic relief would seem to be sufficient to warrant a more prevalent employment of such operations. And yet in a period of about twenty years, comparatively little has been done. Sauerbruch's Clinic at Zurich is watched with interest, but elsewhere the statistics are fragmentary. Many individuals might report, or have reported, from five to fifteen cases. If any well-trained American surgeon would devote himself exclusively to the study of the extrapleural surgical therapy of pulmonary tuberculosis, in conjunction with the director of a large tuberculosis sanatorium, I believe that, in a comparatively short time, his results would be so beneficial that a large surgical clinic would be established for this form of therapy.

#### TUMORS OF THE ESOPHAGUS

May the members of this association who have long labored in this subject continue to carry on. Would that their results were a greater reward for their undying persistence. If the intrapleural route can be perfected, the many dangers of the transpleural route are obviated. And here, again, we are confronted with the possibilities of radiotherapy and roentgenotherapy which may independently, or in conjunction with less radical surgery, produce results.

#### SUMMARY

To sum up the status quo of thoracic surgery, I argue that the progress of the last fifteen years has not been so creditable as we are sometimes inclined to suppose. The experimental field was laid open to us by the discovery of differential pressure, without which the dog's thorax cannot be widely opened for experimental surgery. Instead of making great use of this adjunct, we have neglected it in our zeal to employ differential pressure in operations on man, in whom its usage is rarely a necessity, though occasionally an asset. Experimental surgery has been conducted essentially in other regions of the body, although there are innumerable problems in thoracic surgery which must be solved by animal work. It behooves the workers of this association not only to carry on personally more experimentation, but to encourage our younger associates to engage in this type of laboratory experimentation. The annual programs of this association are lamentably lacking in reports from surgical laboratories, a fact which exposes the prevalent lassitude. Clinically, too, a far greater effort can be made. The surgery of the neck, the abdomen, the pelvis, the genito-urinary system and the extremities is far cleaner, more successful and more

remunerative No surgeon today confines himself to the thorax, and, doubtless, this is in a sense fortunate, but our prevailing tendency is to give our thoracic cases the least attention The internist is often heard lamenting that he cannot find a surgeon who will take any interest in his cases of thoracic disease

Now that the interruptions of war are over, and our attention is again centered on the study of the diseases of civil life, I look for renewed progress in the chosen subject of this association



# SURGICAL TREATMENT OF THE ESOPHAGUS

HERMANN FISCHER, M D

NEW YORK

Eighteen years have passed since Sauerbruch solved the problem of attacking intrathoracic organs by means of his differential pressure chamber. By this invention, it was hoped that it might be possible to reach and remove carcinomatous tumors of the intrathoracic part of the esophagus which hitherto had been impossible of approach. In the beginning, the complicated apparatus stood in the way of popularizing the method, and only a few larger institutions were fortunate enough to be able to provide themselves with this costly differential pressure chamber. It has been my good fortune to be connected with an institution, the Lenox Hill Hospital (formerly German Hospital) in New York, which was the first in this country to erect a Sauerbruch chamber, as a result of the untiring efforts and enthusiasm of one of our members, Dr. Willy Meyer.

In the course of years, the method of using differential pressure has become materially simplified by the introduction of the Meltzer-Auer intralaryngeal and intrapharyngeal inflation and other positive pressure apparatus, such as those of Tiegel, Brauer and others. These simplified apparatus have brought the possibility of attacking the intrathoracic organs within the reach of every surgeon who is interested in the work.

After Sauerbruch's first publication, enthusiasm rose high, and an enormous amount of experimental work on animals was done, followed by trials of the methods on the human being. Unfortunately, the ultimate results of these operations on the human being did not keep pace with the results of experimental work on animals. This, of course, had a subduing influence on the enthusiasm of a good many workers in this difficult and complicated field, and at the Thirty-Ninth Congress of the German Surgical Society, Kuttner said that, on account of the bad results which he had had, he had given up the operative treatment of carcinoma of the intrathoracic portion of the esophagus.

However, in our institution, a few men kept the light of enthusiasm burning in spite of disappointment after disappointment, until Torek, by his brilliant operation in 1913 which culminated in a lasting cure of carcinoma of the thoracic portion of the esophagus in a woman, proved beyond doubt the feasibility of transpleural esophagectomy. Up to the

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\* Read before the American Association for Thoracic Surgery, Washington D. C. April 29, 1922.

year 1914, intense and ingenious work had been done in this field. Then the unfortunate catastrophe of the World War came, and with it our subject almost entirely disappeared from the surgical literature in Germany, and for that matter in Europe.

Carcinoma of the esophagus is no longer a disease with 100 per cent. mortality, as it was heretofore. This fact stands out irrefutably, and beckons and pleads with us not to fold our hands and withhold from these unfortunate patients a possible chance of cure, however slim it may be in the individual case.

Many years before we knew how to avoid a fatal pneumothorax and before it dawned on us to attack the thoracic esophagus transpleurally, surgeons tried to reach the esophagus, in cases of injury or the presence of a foreign body, through the posterior, and even anterior, mediastinum, without opening the pleura. The first surgeon to work out a method of approach to the esophagus through the posterior mediastinum was a Russian by the name of Nasiloff.

The patient lies on the abdomen, the left arm is pulled upward a hand's breadth from the vertebral column and parallel to it, an incision is made through the skin and musculature down to the ribs. At each end of this incision, a horizontal incision is made, which ends at the vertebral column. This quadrilateral flap is dissected up from the underlying ribs. If the operator wishes to reach the upper portion of the thoracic esophagus, this flap is made high on the left side, and pieces of the third to the sixth rib are resected. In case he wishes to reach the lower thoracic portion of the esophagus, the flap is made over the right and lower portion of the back, and pieces of the lower ribs are removed. After careful and double ligation of the intercostal arteries, the costal pleura is carefully pushed away from the ribs. He then enters the posterior mediastinum without opening the pleura. In this way, the aorta and the esophagus are reached with anatomic forceps or a grooved director, the esophagus is freed from the loose connective tissue which surrounds it, and it is then pulled out of the wound by a Langenbeck's resection hook.

This procedure has been employed by a number of surgeons<sup>1</sup> who, to suit their special cases, have more or less changed or improved it. Milton's method, described by Enderlen,<sup>2</sup> is interesting. He made a long incision from the thyroid cartilage to the ensiform process and divided the sternum in its long axis. By pulling the separated halves of the sternum apart, he gained a space from 5 to 6 cm. in width. Through

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1 Quenu, Hartman, Potarca, Brvant, Rehn, Levl, von Hacker, L. Heidenhain and Bourienne.

2 Enderlen. Ein Beitrag zur Chirurgie des hinteren Mediastinums, *Deutsch. Ztschr. f. Chir.* 61.

it, he asserts that he was able to reach the anterior and posterior mediastinum. Milton used this method in the removal of tuberculous glands from the anterior mediastinum. The patient recovered from the operation.

Enderlen,<sup>2</sup> who has carefully studied and critically reviewed these different methods, recommends the following operation as the best approach to the esophagus through the posterior mediastinum.

A rectangular skin flap is formed, reaching from the third to the ninth thoracic vertebra, with its base toward the vertebral column, its outer edge close to the median border of the scapula. The soft parts are severed down to the ribs, and the flap is reflected. Subperiosteal resection of a piece of the eighth rib, 10 cm. in length, is performed. Subperiosteal resection of the eighth rib is the most difficult part of the operation. After this has been done, it is comparatively easy to lift the next higher rib away from the pleura and cut it. With some practice, one can thus reflect a flap containing the ribs from the eighth to the fourth, including the intercostal muscles, without opening the pleura. It is best to remove this whole flap, as its reposition is an unnecessary, complicating procedure. The pleura costalis is then carefully stripped off ventrally, and toward the spinal column. One has to be careful not to lift off the sympathetic trunk with the pleura, although Rehn believes this danger is remote. As soon as one has reached the anterior surface of the vertebral column, insertion of an esophageal bougie is recommended in order to facilitate recognition of the organ.

Enderlen states, and Sauerbruch is of the same opinion, that the next procedure, the dissection of the esophagus from its bed without injury to its walls, cannot be done. Its muscular coat is easily injured, and even both coats are easily torn. It is, however, possible by this method of approach to close a longitudinal wound in the esophagus by suture as Rehn<sup>3</sup> has demonstrated. Enderlen believes it impossible to resect the esophagus in its entirety and to restore this lumen by a circular suture. Complete isolation of the esophagus and drawing it sufficiently out of the wound, he considers impossible. By this maneuver, the nutrient vessels would be injured to such an extent that a necrosis of their walls must ensue. That this opinion is not founded on actual clinical facts was later proved by Zaaier<sup>4</sup> of Leiden.

In a case of a large diverticulum, the esophagus was completely isolated, two of its arteries were tied, and the esophagus was brought forward and sutured to the edges of the thorax wound. His operation proved that it is possible to isolate the esophagus to a great extent without grave disturbances of its circulation and subsequent danger of secondary necrosis. This demonstration of Zaaier's has become of fundamental importance in the later developments of resection of this organ.

<sup>3</sup> Rehn. Operationen an dem Brustabschnitt der Speiseröhre, *Arch. f. klin. Chir.* **57** 733 1888.

<sup>4</sup> Zaaier. Oesophagostomia Thoracalis. *Beitr. z. klin. Chir.* **77**.

Results with the posterior approach through the posterior mediastinum having been poor, this method was abandoned. Von Mikulicz<sup>5</sup> was the first to try to reach the esophagus from in front. This necessitated a broad approach through the thorax, which could only be accomplished under some form of artificial respiration. He tried the method in attempting a resection of the tumor in three patients with carcinoma of the esophagus.

Dobromissloff,<sup>6</sup> in Tomsk, later tried, in a similar fashion, to extirpate the esophagus. He operated on dogs. Under ether narcosis, a tracheotomy is performed, and artificial respiration established by means of an electromotor. A large flap, from 10 to 15 cm long, is made of the thickness of the entire left thorax wall, from the sixth to the tenth rib, with the pedicle toward the back, within from 2 to 3 cm of the spinous processes. The flap is reflected backward, and the intercostal vessels are tied. The pleura over the esophagus is incised, from the root of the lung down to the diaphragm. The vagus is severed. Blunt dissection of the esophagus is accomplished, usually accompanied by very little bleeding. A piece, about 3.5 to 4 cm long, is excised, and the two ends are reunited by an end-to-end silk suture in two rows, from 1 to 1.5 cm of the muscularis being taken up by the suture which does not penetrate the mucosa. This is followed by reposition of the thorax flap, suture of the intercostal spaces, musculature and skin. Air which had entered the thorax during operation is aspirated, after which artificial respiration is discontinued.

Dobromissloff reports a case in which a dog died three weeks after operation from overdistention of the stomach with food. At necropsy it was shown that the suture of the esophagus was well healed and intact, with a slight dilatation above. Experiments on the human cadaver convinced him of the feasibility of the operation, and he recommended its trial in suitable cases. It seems, however, that no other surgeon followed his suggestion, at least the report of no such operation has appeared in the literature. Sauerbruch has performed thirty experimental resections of the esophagus under artificial respiration with the same bad results, for which he mainly blames the artificial respiration.

#### PREVENTION OF PNEUMOTHORAX

The difficulties with which the surgeon is confronted are many and great. The greatest problem, the prevention of pneumothorax, has been overcome by the employment of differential pressure in some

5 Von Mikulicz. Ein Fall von Resektion des Carcinomatösen Oesophagus mit plastischem Ersatz des excidirten Stückes. *Prag med Wchnschr* 11 93, 1886.

6 Dobromissloff. Ein Fall von transpleuraler Oesophagotomie im Brustabschnitte d. Speiseröhre. *Zentralbl f Chir* 1901 p 1.

form either negative or positive. The great controversy concerning the relative merits of plus or minus pressure has subsided, and it has been proved that there exists no difference in the two procedures. In fact, positive pressure, which for Sauerbruch and his followers has been anathema, has practically superseded negative pressure on account of the ease with which it can be employed. The greatest bugbear was to find a method of reconstructing the lumen of the esophagus by suture. Although it was demonstrated by experiments on dogs not only that a suture of the esophagus was feasible, but also that a perfect union without interference with deglutition could be obtained, it was also shown that in the human being suture of the esophagus invariably resulted in disaster. There are various anatomic reasons for this. The esophagus, which is only a thick, muscular tube, consisting of a muscular and a mucous coat, has no serosa like that of the intestine, which quickly agglutinates and forms adhesions. The mucous coat is rather tough and well adapted to suturing, the muscular coat, however, is very easily torn and the sutures cut through easily. Although it is possible to stretch the tube to such an extent that even a gap of from 7 to 10 cm. can be bridged over, the tension is so great that the sutures do not hold. Even if very much smaller pieces are resected and brought together and sutured, the tension from vomiting and retching becomes so great that the sutures tear through.

A good deal of ingenuity has been used to obviate this danger. Biondi, as early as 1896, published a method of resection of the intrathoracic portion of the esophagus which later became a most important cornerstone in the development of esophageal surgery. He opened the left pleura wide, incised the left side of the diaphragm, pulled a portion of the stomach into the pleural cavity, resected a piece of the esophagus, closed the lower stump, and made an anastomosis of the oral stump of the esophagus with the stomach. Mikulicz in February, 1904, resected 4 cm. of the lower part of the esophagus in a dog and made an end-to-end anastomosis. By mobilizing the esophagus in the hiatus of the diaphragm, he transposed the lower end, with the suture line, into the abdomen and stitched the diaphragm to the esophageal wall above the anastomosis. This experiment was successful. The dog lived for six weeks and died of a subsequent enteritis. Necropsy revealed no pneumothorax, no empyema, slight adhesions of the lower lobe of the left lung to the diaphragm, slight stenosis at the site of suture and adhesions of the suture line to the stomach and duodenum.

Anschutz demonstrated that a part of the stomach can be transferred into the thoracic cavity by pulling it through the hiatus of the diaphragm without interfering with respiration or the function of the diaphragm or of the stomach itself. Sauerbruch therefore, tried to

bridge the gap in the esophagus by pulling the stomach upward. But all of his experiments, performed to obtain a good result either by suture of the esophageal stumps, or by closure of the lower end of the esophagus by inversion into the stomach and implantation of the upper end of the esophagus into the stomach, were more or less failures. He finally gave up the suture entirely and made the anastomosis between the stomach and esophagus by means of a button. He states that after mastering the technic he very rarely lost a dog after such an operation. Avoiding tension by transposing the stomach into the thoracic cavity, and discarding the suture, he believes, was a distinct advance. After the operation, a thorough cleansing of the thoracic cavity with physiologic sodium chlorid solution and the use of Lugol's solution to create early adhesions of the parts were recommended by him.

Whether this method of transposition of the stomach into the pleural cavity is really of no significance to the animal is questionable, and Levy is justified in doubting the advocacy of the procedure. Sauerbruch himself reports the sudden death of two animals, several days after the operation, from a diaphragmatic hernia of the stomach, the latter organ completely filling the left pleural cavity. Oni and Karasawa,<sup>7</sup> in their experiments on transposition of the stomach, lost two dogs immediately after incision of the diaphragm. Another animal died of a pulmonary disease, two others developed diaphragmatic hernias, in consequence of which one died five days after operation. The whole stomach, spleen and large omentum were lying in the pleural cavity. The other animal was fairly well and vomited only after over-feeding. It was killed one hundred and thirty-five days after operation. Necropsy revealed a rent, 3 cm. long, in the left part of the diaphragm. In the left pleural cavity were found the whole stomach, with the spleen, a loop of small intestine, the transverse colon and the greater omentum.

Freund<sup>8</sup> had about the same experience. Of six dogs operated on, only two lived. One died four months after operation of distemper, the other died six months after operation of an acute pancreatitis. In the first animal the whole stomach was found in the pleura, and, in the second dog, a large part of the greater omentum and the spleen.

After the publications of von Mikulicz, Sauerbruch and Anschutz, on their experimental work a great many other surgeons tried to solve the problem of suture of the esophagus. I shall mention only Green, Janeway and Willy Meyer, in this country, who have all tried, by

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<sup>7</sup> Oni and Karasawa. *Beitrag zur Chirurgie der Speiserohre*. Deutsch. Ztschr. f. Chir. **124**: 574, 1913.

<sup>8</sup> Freund. *Experimenteller Beitrag zur Querresektion des Oesophagus*, Beitr. z. klin. Chir. **88**: 423, 1914.

ingenious modifications to work out a secure anastomosis between esophagus and stomach or between the two stumps of the esophagus. All their endeavors were failures. The use of a button for intestinal anastomosis, or its modifications, by Tiegel gave no more encouraging results.

After all these failures to establish a firm suture, Levy<sup>9</sup> came to the conclusion that in order to gain any headway in the operation for carcinoma of the esophagus, the whole esophagus, from the cardia to its cervical portion, should be removed. As far back as 1898, Levy had done a large amount of experimental work on operations for the removal of carcinoma of the esophagus. For many years, curious to say, his work was little known to the profession, at least, it seems to have attracted little attention. He operated on dogs, in which he first established a gastrostomy. Thereupon, he opened the esophagus at the neck and inserted a stomach tube, armed with a silk thread, 1.5 meters long. This tube was pushed down into the stomach until it could be pulled out through the gastrostomy opening. The thread was secured, and the stomach tube withdrawn. The thread was now lying inside the esophagus. The esophagus was then severed in the cervical region, and the upper aboral end of the esophagus was closed with the thread. By carefully pulling on the lower end of the thread which projected from the gastrostomy opening, he was able to invert the whole esophagus, pull it out through the stomach, and resect it outside. Levy tried this procedure on human cadavers, but came to the conclusion that it was not feasible in man. He says, "If you try to pull down the esophagus through a stomach fistula, you remove a tube which, in the cervical portion and a little further down, contains all layers of the esophagus. The largest part of the tube, however, consists only of mucous membrane and a more or less complete layer of ring-musculature, whereas the longitudinal muscle fibers are left behind."

Kelling,<sup>10</sup> in 1902, worked out a combined method of intrathoracic and abdominal resection of the lower part of the esophagus in which the whole esophagus was removed from the thorax and pulled out through a wound in the neck. He mobilizes the tumor by opening the thorax under artificial respiration. After this has been accomplished the thorax is closed. The abdominal cavity is then opened, the esophagus mobilized at the hiatus of the diaphragm and cut through. A wooden cylindric plug is then inserted into its lumen, and a rubber finger-cot pulled over it to prevent leakage from the esophagus with the subsequent danger of mediastinal infection. The esophagus is then

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<sup>9</sup> Levy. Versuche über die Resektion der Speiseröhre. Arch. f. klin. Chir. 56: 839, 1898.

<sup>10</sup> Kelling. Zentralbl. f. Chir. 1902.

invaginated by means of a string and pulled up into the neck. Here an incision is made and the esophagus pulled out through the neck wound. Nutrition is kept up by gastrostomy feeding. This method of removing the entire esophagus from the thorax has become an important principle in the development of the operation of resection for carcinoma. Kelling himself has not followed this idea because he deemed the procedure too dangerous and too complicated to be tried on the human being. Kuttner and Schneider also advocated the removal of the whole esophagus and advised closing the oral end. This procedure, however, is unpractical, as the closed end of the esophagus invariably leaks.

Kuttner succeeded in removing a carcinoma of the upper thoracic portion of the neck by mobilizing the cervical and upper thoracic portions of the esophagus through an incision in the neck. He was able to pull the esophagus with the tumor out of the cervical wound and resect the tumor outside the body.

In 1912, Ash, independently and without the knowledge of Levy's work, succeeded in working out an ingenious method of extracting the whole esophagus, which he finally used in a case of carcinoma of the cardia which had extended upward into the intrathoracic part of the esophagus and downward to the stomach. The patient made an uneventful operative recovery, but, unfortunately, died of inanition in consequence of insufficiency of the gastric fistula. His patient is one of the few that recuperated fully after the operation. His procedure was as follows:

The patient was turned partly on his right side. A large curved incision was made along the left costal border, starting at the ensiform process and extending backward. The rectus, obliquus externus and internus muscles were severed. The muscles were widely separated especially posteriorly, in order that the left costal arch might be lifted upward. After careful hemostasis the transversalis muscle and fascia were severed, and the peritoneal cavity entered. The left lobe of the liver was pushed over to the right, and the left costal arch lifted upward. This maneuver exposed the whole stomach and the cardia beautifully. The upper part of the stomach was involved by a large tumor, which seemed to have started at the cardia and extended over to the stomach. At the hiatus, the tumor could be distinctly felt involving the lower portion of the esophagus in a circular manner. The upper margin of the tumor could not be palpated through the diaphragm. As it seemed possible to remove the tumor the abdominal cavity was temporarily tamponed. The cervical portion of the esophagus was then exposed by an incision, 8 cm. long along the inner border of the sternocleidomastoid muscle. It was mobilized by blunt dissection, care being taken not to injure either recurrent nerve or the inferior thyroid artery. Preliminary packing of the wound in the neck followed. The patient was then put under differential pressure. Operation was continued from the abdomen. The tumor was pulled down a little, and the peritoneum was incised on the anterior surface near the hiatus. This incision was carried over to the serosa of the cardiac portion. The finger was then inserted into the hiatus and the tumor was bluntly mobilized from the muscular portions of the



diaphragm, by working upward into the mediastinum with the finger. It was believed that the tumor surrounded the lower part of the thoracic portion of the esophagus to a distance of about 5 cm. After insertion of a Langenbeck hook into the hiatus, it was seen that the left vagus nerve was firmly embedded in the carcinomatous tumor. In trying to isolate the tumor on the right and left sides, both pleural cavities were opened.

On further mobilization of the tumor, posteriorly, the right vagus nerve was also found implicated in the disease process. In consequence of the manipulations necessary for the isolation of the esophagus and vagus, the pulse dropped to 44 per minute and became slightly irregular. In order to avoid further irritation of the vagi, both were cut through with scissors. No reaction on the part of the heart was noticed. The esophagus was clamped, 2 cm. above the tumor and a ligature, about 1 meter long, was tied around the esophagus immediately above the clamp. The ends of this ligature were left long. The esophagus was pulled down farther, another clamp was placed immediately above the tumor, and the esophagus was divided between these two clamps. The upper stump of the esophagus was carefully wiped clean, and the lower stump, after the omentum minus and the left gastric artery had been tied, was displaced downward. The narcotizer then introduced into the esophagus a long flexible steel rod with an eye at its end. As soon as the steel rod was introduced, the operator grasped the lower end of the esophagus with his thumb and index finger thereby being able to feel the rod distinctly through the walls of the esophagus. A suture was then passed through the wall of the esophagus and through the eye in the steel rod. This suture was left about 12 cm. long. By carefully withdrawing the steel rod from the esophagus, the walls of the esophagus were inverted, and the whole tube extracted until the lower esophageal stump appeared in the mouth of the patient. A small gauze compress was inserted into the mediastinum. Through the wound in the neck, one could see how the esophagus glided upward. The moment the lower invaginated end appeared directly above the jugulum, extraction was stopped. The long ligature which projected from the invaginated funnel was secured, and the fixation thread of the steel rod cut by the narcotizer. By pulling on the long ligation thread which projected from the neck, the invaginated portion was again disinvaginated through the neck wound. The skin over the sternum was undermined, an incision was made into the skin lower down and the esophagus pulled through this tunnel, and its lower end brought out of the skin wound so that it projected for about 25 cm. Tension on the esophagus was carefully avoided. A rubber tube was tied into the esophageal stump, and the wound in the neck was carefully closed, there being danger of pneumothorax. The tampon was then removed from the mediastinum, and there was practically no hemorrhage. The hiatus of the esophagus was closed by a running suture and buried, a second row of sutures catching up the peritoneum and a little of the muscular wall of the diaphragm to make the closure air-tight. This finished the removal of the esophagus. The tumor of the stomach was then resected, the stomach wound closed and a gastrostomy established. The operation required one hour and twenty-five minutes.

Ach is of the opinion that his method can be successfully employed in carcinoma of the cardia and of the lower end of the esophagus up to 8 cm. above the diaphragm. Tumors which involve the upper thoracic portions, in the neighborhood of the bifurcation, must be attacked by an endothoracic operation, with a preliminary gastrostomy.

Rehn<sup>11</sup> repeated the method of extraction of the esophagus by invagination, after Ach. In two of his animals, there was a large hemorrhage into the mediastinum. In order to avoid this, he tried to invaginate only the mucous membrane of the esophageal tube, in which he easily succeeded. He tried the same method on the human being, however, without success, as the mucous membrane in man is not resistant enough. In his operations on human beings, he invaginated the esophagus in toto, downward and upward, and made the same observation as Levy, that in invagination downward, the outer longitudinal muscular coat stays behind. Contrary to Levy, however, he considers this a great advantage because it does away with the danger of mediastinal hemorrhage.

Since the advent of differential pressure, all of our endeavors to resect a tumor of the esophagus have been by the transpleural method. Although the advantage, so far as a good approach to the organ and ease in working are concerned, was great, the operation with its attending shock was so formidable that results were poor. The pleura is very sensitive to infections, and the irritation of the membrane during the long manipulations in the thoracic cavity produce powerful reflexes. To this is added the trauma to the lungs and their long exposure, which are weighty factors in the production of postoperative pneumonia. The complication of secondary pneumothorax as a result of the suture line not being air-tight is also a danger, although less great. It is undoubtedly true that, in great part, failures can be attributed to the following causes: infection of the pleura with consequent empyema, pyopneumothorax, pneumonia and postoperative shock. The last, however, can be successfully overcome, as numerous cases of my own and of others have shown. A good many patients have lived several days after the operation, and have finally succumbed to infection. A patient in whom thoracotomy has been performed, with exploration and closure of the thorax wounds, usually makes a good operative recovery, and then dies, many months later, of the disease itself. Air-tight drainage of the pleural cavity is demanded by many surgeons of experience, as Kuttner, Willy Meyer, Tiegel and Mikulicz. Sauerbruch does not advise drainage, because he believes it hurts more than it helps. Torek's successful case was not drained. Rehn also recommends drainage in cases in which, during the operation, no direct infection has occurred, because the pleura reacts, in every case, with a fluid exudate which accumulates very quickly. On the other hand, drainage of the thoracic cavity is not irrelevant as the drainage tube is a source of continued irritation and means a constant communication with the outside. Although we now

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11 Rehn, Edward. *Oesophagus-Chirurgie*. Jena: G. Fischer, 1914.

have a number of air-tight drainage methods, they must all still be considered a disadvantage in intrapleural operations

It is not surprising, therefore, that lately a number of surgeons have returned to extrapleural operations in carcinoma of the esophagus. Among them are Kummel,<sup>12</sup> Rehn, Levy<sup>13</sup> and, in this country, lately, Lilienthal.<sup>14</sup> Kummel has operated on eighteen patients with carcinoma of the esophagus. In nine cases, it involved the cardia, and, in nine cases, the thoracic portion of the organ. In consequence of theoretical consideration and experiments on the cadaver, he prefers the abdominal route for carcinoma of the cardia. He mobilizes the cardia in the hiatus, and the lower part of the esophagus as high up as possible, by blunt dissection with the finger. The cardia and the lower end of the esophagus were pulled down as far as possible, and the esophagus divided between clamps. After resection of the tumor, he tried to make an anastomosis between the esophagus and stomach. Under favorable conditions, he succeeded in pulling down 12 cm. of the esophagus, and on the cadaver, even 14 cm. His results, however, were not very encouraging on account of the insecurity of the suture. He had one operative success in a man who died one year later from metastases. In seven cases, the carcinoma was located in the thoracic portion, from 22 to 38 cm. from the teeth. According to the location of the tumor, operation is performed from the neck or by a large trap-door flap incision in the back, with resection of a number of ribs on the right or the left side of the vertebral column. In one case he mobilized the esophagus with the tumor and placed it outside the chest, sliding a skin flap under it with the idea of performing a plastic operation later. In cases of high intrathoracic carcinoma, he prefers the dorsal method, and, if possible, performed extrapleurally. An identical method was used in a patient operated on lately by Lilienthal, with a beautiful operative success.

Kummel, who has continued to work steadily on our problems, has lately published a method in which the entire esophagus is removed without opening the pleural cavity widely. The removed esophagus is replaced by the stomach, which is displaced from the abdominal cavity into the posterior mediastinum. The anastomosis between the esophagus and the stomach is made in the neck. In carcinoma of the cardia, he now proceeds as follows. The abdominal cavity is opened in the

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12 Hauch. Ueber unsere Radikaloperationen beim Karzinom der Speiseröhre in ihrem thorakalen und abdominalen Abschnitt, *Beitr. z. klin. Chir.* **92** 121 1914.

13 Levy. Weitere Beiträge zur Resektion der Speiseröhre, *Arch. f. klin. Chir.* **119**, p. 20.

14 Lilienthal, Howard. Carcinoma of the Thoracic Oesophagus. Extrapleural Resection and Plastic. *Ann. Surg.* **74** 259 (Sept.) 1921.

median line Marwedel's reflection of the costal border is rarely necessary The cardia and the adjacent lower portion of the esophagus are mobilized, and the stomach is mobilized after the method of Kirschner<sup>15</sup> An incision is made into the neck, and mobilization of the cervical and upper thoracic portions of the esophagus is accomplished by careful dissection with the finger In a short thorax, he succeeded, in a relatively easy manner, by working with one hand in the neck and the other in the abdomen, in mobilizing the whole length of the esophagus in the posterior mediastinum If the entire organ is not dissected loose by the method described, the last strands of tissue that hold the esophagus can easily be torn by a gentle pull Then the esophagus and the mobilized stomach are pulled upward until the tumor projects through the neck wound, the stomach following The new esophagus is formed by the stomach lying in the posterior mediastinum A possible tear in the pleura is tamponed by the stomach and has no bad effect, as the operation is, of course, performed under differential pressure The tumor is then resected and the stomach is anastomosed with the stump of the esophagus by suture or invagination outside the body Kirschner's transposition of the stomach, replacing the esophagus and thereby changing the stomach into a functioning esophagus, means a great progress in the surgery of this organ The great drawback heretofore was the anastomosis of the lower end of the esophagus and the jejunum, as originally advocated by Kirschner The method as above described by Kummel obviates this defect in Kirschner's procedure

In cases in which the carcinoma is situated high in the thorax, Kummel prefers, as do Rehn and others, the extrapleural dorsal approach If the tumor proves operable, it is mobilized extrapleurally, downward and upward After opening the abdomen, the stomach is mobilized according to Kirschner At the same time, another operator dissects the esophagus in the neck, and the esophagus with the stomach is then pulled upward and out of the neck wound, the tumor resected, and the stomach and esophagus united Closure of the abdomen and thorax is accomplished In this fashion, any infection of the pleural cavity is avoided, and with it one great danger of these operations

Kummel has tried this method in many experiments on the cadaver and on animals He also found it comparatively easy in one case in the human being, in which he performed it successfully and on which he promises a detailed report in the near future

The whole operation seems to be a very bold procedure I cannot help asking whether the complete transposition of the stomach into the posterior mediastinum can be borne without interfering with the func-

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<sup>15</sup> Kirschner Ein neues Verfahren der Oesophagoplastik Arch f klin Chir **114** 606 1920

tion of the heart and lungs when the stomach is dilated by the ingestion of food and by gas formation, thereby exerting pressure on the thoracic viscera. These, of course, are only theoretical doubts and scruples and cannot stand in the face of practical experience. However, in the light of our experience with the transposition of the stomach into the pleural cavity, there is a certain justification in raising such doubts. It may be that the stomach, placed extrapleurally in the mediastinum, behaves better than in the open pleural cavity.

Levy, in a late paper, also advocates the dorsal approach if possible, extrapleurally. In order to secure the necessary room, he removed the fourth to the tenth ribs from the angle to the costal cartilage, as Zaaier recommended. He also describes a complicated extrapleural esophageal plastic operation.

#### SUMMARY

Surgery of the esophagus has passed through a long cycle of development, in which several distinct stages can be discerned: (1) extrapleural dorsal approach, with endeavors to reconstruct the lumen by suture, (2) transpleural approach under differential pressure, with an attempt to restore the tube, with or without transposition of the stomach, by suture or buttons of various types, (3) transpleural removal of the whole esophagus, placing the stump outside, from an incision in the neck and later reconstruction of the esophagus by a plastic operation according to the methods of Roux, Wullstein, Lexer, Hirsch, Jianu and others, (4) extrapleural removal of the entire esophagus by invagination (Ash, Rehn), by a combined method from the abdomen and the neck, (5) extrapleural removal by a combined method from the abdomen and neck, or from the abdomen, neck and back, with transposition of the stomach into the posterior mediastinum.

In 1895, Postemski summed up his conclusions about the indications for operations for carcinoma of the esophagus as follows: "There are operations which should not be tried, even on the animal, because failure is certain, and because they can never be applied to the human subject" (*Il y a des opérations qu'on ne doit pas essayer, même chez animaux, parce que l'insucces est certain, et que l'application ne pourra jamais être faite chez l'homme*). Eighteen years have gone by since he uttered these hopeless words. Are they still true today?

We poor mortals must not make prophesies, but looking backward and scrutinizing our work, we are surely justified in taking a more hopeful attitude. It is true our results of today are not such that we should be boastful about them. So far, only in cases of carcinoma of the cardiac portion of the esophagus has the patient recuperated from the operation and lived. These cases were reported by Voelker, Bircher and Kummel. Of carcinomas of the intrathoracic portion only the patient of Torek who is still alive and well after nine years, and that of Zaaier have made full recoveries. In 1921, Lilienthal of New York

published the report of a case in which he succeeded in removing a carcinoma of the intrathoracic portion of the esophagus and restoring the lumen by a skin-flap plastic operation, by his posterior method. The patient later developed a recurrence and died. However, the dogged tenacity with which we have taken hold of this difficult problem bears the seed of ultimate success. Let us not tire, and I am sure that not many years from now many cures will have been accomplished in a disease that was beyond help and hope.

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# POSTERIOR MEDIASTINOTOMY \*

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Extrapleural posterior mediastinotomy is an operation which probably has a surgical value far greater than has been generally supposed. By the methods which I have worked out, the exposure is so complete that not only the posterior but also the middle and superior divisions of the mediastinum can be reached with facility and with comparative safety. The thoracic esophagus can be exposed, and operations on the portion between the lower limits of the aortic arch and the opening in the diaphragm can be safely performed in suitable cases, and, by enlarging the hiatus, it is not unlikely that the cardia may be drawn up within the retropleural space.

Suppurative infection of the mediastinum can be treated by drainage, enlarged lymph nodes and new growths can be reached, the bodies of the vertebrae can be exposed for operative procedures, the entire thoracic aorta can be examined visually, and, in certain not too advanced cases of aneurysm of this vessel, one can easily conceive of the carrying out of operative procedures hitherto considered too difficult for practice. I suggest, for example, the winding of not too extensive fusiform aneurysms of the descending portion of the aorta below the arch with fascia lata strips.

The phrenic nerves, the vagi, the left recurrent laryngeal nerves and the great splanchnics are within easy sight and touch. No doubt, pressure symptoms on one or another of these important structures will, in the future, be relieved by operation. Possibly, even tumors springing from the sympathetic system, such as the ganglion neuromas, may be attacked by this route instead of transpleurally. Finally, obstructing pressure on the thoracic duct may be relieved, or injuries to this important structure repaired.

The pericardium can be approached from behind, and procedures on this remote part can be carried out without dislocating the heart.

Until the present time, mediastinotomy has been a most unusual operation. In the near future, it will become comparatively common. The development of the surgery of this region will present a fascinating series of problems in physiology, in pathology, in diagnosis, including roentgenology, in operative technic, in drainage and in the healing of wounds. As our experience enlarges, timidity will give place to confidence and gradually our brothers who practice internal medicine will

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send us their patients, not as a last resort, but in the reasonable hope that we may accomplish something for them

Until 1921, there were described only two methods of entering and exploring the posterior mediastinum without deliberately violating the pleura first, that of Nasiloff,<sup>1</sup> who resected a number of ribs posteriorly and reached the mediastinum through this opening, second, that of Bryant, who made a trap-door of ribs and soft parts, swinging on a sagittal hinge and exposing a quadrilateral opening with rigid sides and a definitely limited area, and later Enderlen<sup>2</sup> made a similar trap-door but resected the ribs. What little retraction was possible in these operations depended on the spring of the anterior portion of the divided ribs on their cartilages while the upper and lower undivided ribs acted as a bar to the lateral spreading of the wound. Also, in gaining access to the posterior mediastinal space, the scapula would have to be dissected away and ribs resected beneath it.

#### AUTHOR'S TECHNIC

The principle on which this approach depends is that of the retraction of the divided ribs at right angles to their long direction, shingling them, one upon the other, thus making the deep exposure from below upward, the extent of available space being determined by the length of the wound, especially that portion which divides the intercostal extra-pleural structures.

*Preparation*—In addition to the general examination of the patient in order to determine his fitness to withstand an operation, the blood pressure should be ascertained, and, if the systolic is lower than 125, digitalis should be administered for the twenty-four hours before operating. A tincture of standard potency in doses of from 15 to 30 minims, every four hours, should accomplish digitalization in a day.

*Position on the Table*—The patient should lie on the right side, but turned about 30 degrees toward the front so as to bring the field of operation into the most convenient position for the surgeon. The thighs should be flexed and held by straps passed under the table. The right arm may be slightly behind the patient, the left arm drawn forward and a little upward. The position of the body must be maintained by means of large sand pillows. A pillow or the bridge of the operating table will raise the body into the position of a moderate scoliosis.

*Anesthesia*—Ether or nitrous oxide and oxygen, or a combination or sequence of two or more, when skilfully administered will give a

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1 Nasiloff. *Vrach* 9 481, 1888.

2 Enderlen. Ein Beitrag zur Chirurgie des hinteren Mediastinum, *Deutsch Ztschr f Chir* 61 441, 1901. Enderlen Hotz and Porzelt. Beiträge zur Chirurgie des Oesophagus, *Ztschr f d ges exper Med* 3 108, 1914.

quiet, safe narcosis, though I have fully exposed the mediastinum with local anesthesia without the slightest expression of pain by the patient until the sensitive nervi vasorum of the aortic sheath were manipulated. If a general anesthetic is used, preparations must be made for the immediate application of differential pressure, for there is danger that both sides of the chest may be opened when stripping the pleura forward. At the level of the eighth and ninth dorsal vertebrae, the right pleura often sends a fold across the median line for an inch or more into the left chest, and, if the left pleura has been accidentally torn and the right is also opened, death will quickly follow unless there is positive pressure in the air passages or negative pressure at the wound. If neither pleural sac is injured, ordinary inhalation narcosis is all that is necessary.

*Operative Procedure in Low Posterior Mediastinotomy*—An incision is made on the ninth rib, beginning 7 or 8 inches (17.7 or 20 cm) from the spine and running backward along the rib to the edge of the long spinal muscles, then curving upward, parallel with the spine for four or five interspaces. The ninth rib is resected subperiosteally as far as the wound will permit, beginning just anterior to the angle. But the mere reaching of the posterior mediastinal space can be accomplished with a much shorter resection, or possibly even by merely dividing the rib. The normal pleura is extremely thin and will tear unless the greatest care is exercised. When the resection is complete, the finger is inserted slowly between the posterior unresected part of the rib and its periosteum, peeling this membrane and the pleura forward, away from the posterior chest wall. In this region, the attachment of the pleura to the parietes is much less intimate than it is more anteriorly, so the stripping is easier. Soon the pleura will be found to have separated from the eighth rib, and this bone can be divided with powerful cutting forceps while the finger passed under the rib acts as a guard. The pleura, beneath which the lung can be seen gliding smoothly, is then worked still farther forward, two or three fingers of the right hand being used for the purpose, and the seventh rib is treated as was the eighth. The stripping becomes easier, and often the pleura literally falls away from the mediastinum, especially in the upper part. As many of the next upper ribs as may be required for the exposure are then divided close to the spine, and the pleura and lung are peeled forward with increasing gentleness until it appears that enough space has been made. With a broad blunt retractor against the lower edge of the eighth rib a firm pull is exerted at right angles to this structure, and the first landmark to come into view will be the great splanchnic nerve, as it lies on the posterior chest wall part way up the elevation formed by the bodies of the vertebrae. When the pleura is pressed still farther forward the descending aorta is felt and is next laid bare together with

the left part of the vertebral bodies which are covered with fascia. In front, we now have the esophagus with the pneumogastric nerves, the right, more posterior one, being easier to locate. The recognition of the esophagus by sight or touch is not easy, even when a good sized stomach tube has been inserted through the mouth as a guide. I have, therefore, devised a diaphane which consists of a rubber tube, from 32 to 40 caliber, into the end of which is fitted a little electric lamp, the wires passing through the tube to a small hand battery. An assistant passes this into the esophagus through the mouth, and the light, on being flashed, shows through the tissues with a bright crimson glow, instantly indicating the location of the lumen of the organ. The esophagus is nearly always carried forward with the pleura and pulmonary ligament, much as the ureter is drawn forward with the peritoneum.

There is a netlike layer of tissue which holds the esophagus and the descending aorta together and is continuous with the adventitia of the artery and probably with the pulmonary ligament. This may be lifted from the vessel with forceps, divided with scissors, and partly stripped away to facilitate orientation of the esophagus. But rolling the aorta from its position is dangerous, for its intercostal branches on the far side may be torn, and the resulting hemorrhage may be difficult to control. In one of my cases, the aorta, an extremely thin-walled specimen, was torn by forceps in attempting to check bleeding of this kind, with a fatal result.

In exposing the esophagus, the two principal points are to guard against vagus shock and to avoid entering the pleura. The vagus may be temporarily blocked, as advised by Torek, by applying to this region, above the place where we are dissecting, a little 5 per cent cocaine on a cotton pledget. To keep the pleura intact, we must be most gentle in our manipulation, and every effort must be made to identify the right pleural reflection. The esophagus is not covered by a glistening coat as are the normal intestines, but its outer layer consists of muscle which can too easily be torn by rough handling, and the lumen of the esophagus accidentally entered. The right, more posterior, vagus, with its plexus gulae, is quickly identified, and the nerve branches of the plexus can be divided with scissors if it is desired to isolate the esophagus. The left vagus is not usually seen. With a large broad retractor, the pleura and lung can then be drawn aside, and the posterior wall of the pericardium exposed.

Freeing the esophagus downward, we may follow it forward with its accompanying nerves to where it passes freely through the hiatus in the diaphragm. But it is not easy or always possible to peel the pleura away from the central portion of the diaphragm.

*The High Operation*—With this procedure, the upper portion of the posterior mediastinum is entered and much of the superior space

is exposed. It is carried out on the same general plan as the operation just described, but it is the seventh or even the sixth rib which is first resected, and the fifth, fourth and third are divided posteriorly. At this level, the approach may be from right or left. The trapezius and rhomboid muscles are cut, and the scapula drawn far forward. The separation of the pleura from the chest wall is distinctly easier than it is below, and this sac, with its contained lung, may be pressed downward from the superior opening of the thorax, exposing the entire aortic arch with its branches. The trachea and its bifurcation, the esophagus and the other structures of this region can be seen and handled with facility. We are now operating above the cardiac branches of the vagus, so the cocainization of the pneumogastrics is more important here than it is below.

The left side appears to be the more suitable avenue of approach in opening the lower part of the posterior mediastinum because the aorta, which is the main landmark, lies first to the left of the bodies of the vertebrae, and gradually works over toward the median line, which it almost reaches at a horizontal plane which passes through the tenth rib at the place where it joins the spine. The esophagus in the upper part of the thorax is toward the right of the aorta but comes more directly in front of it as the artery swings toward the midline. Approaching from the left, also, we find that the pleura of this side does not have the complicating fold which is found on the right where, as mentioned above, the sac often crosses to the left side. In pushing the pleura forward after the esophagus is reached, the pulmonary ligament is torn. To the operator, this ligament, in this part of the operation, is not in evidence and it appears to him as if the pleura were pushed directly away from the esophagus. As a matter of fact, of course, the pulmonary ligament is bluntly divided, although it is not usually identified. If the right pleural process should happen to be torn, there will be an immediate and audible rush of air into the right pleura, and it is at this time that differential positive pressure must be applied, which, as stated above, is all the more important if a hole has been torn in the left pleura as well. This accident occurred twice in my experience. One of the cases is worth reporting briefly, a complete record having been published previously.<sup>3</sup> During a dissection in a case which proved to be an inoperable cancer of the esophagus, I was attempting to isolate the normal part of the gullet when the right pleural process was torn. There was a sound of rushing air and the heart's action became very irregular. The left pleura, which was fragile had been already torn, and intrapharyngeal pressure had to be applied. Cyanosis, however, occurred, with extremely shallow

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3 Lihenthal Howard. *Ann Surg* 74 259 (Sept.) 1921

breathing, and I thought that a fatality on the table was imminent. The chest was quickly and completely closed, and the patient recovered so that he left the table in good condition, dying, however, forty-eight hours later. A postmortem wound inspection revealed air and a little bloody serum in the right pleura. It is probable that death was caused by pneumatic and circulatory changes in both sides of the chest in an old and cachectic patient.

I have explored the posterior mediastinum eleven times for carcinoma of the esophagus, and some of the histories have been reported.<sup>3</sup> I have twice explored the superior mediastinum, together with the upper part of the posterior. In both, exposure was perfectly satisfactory, and the mediastinotomy itself was not so difficult as in the lower operation. The arch of the aorta and its branches, particularly those on the left side, were perfectly exposed. Both operations were through left-sided incisions.

The accidental entry into one pleural sac does not necessarily mean that the operation must be immediately abandoned. With the aid of differential air pressure, the procedure may be continued, and at its termination, if the wound in the pleura is too large for suture or if the pleura is too fragile to hold the stitches, a covering of gauze or of rubber dam may be laid on the rent, the remainder of the mediastinum packed and the external wound closed. In a few days, the lung will have expanded and will have sealed off the rent in the pleura. I first observed this in the case of a woman, aged 63, who had a carcinoma of the esophagus just below the aortic arch. There was also a large metastasis in the right upper pulmonary lobe, which had unfortunately been misinterpreted in examining the roentgenogram. In this case, I found, near the end of the operation, that there was an opening in the pleura, half as large as the palm of an adult hand. The flap of the skin which was to have been used to form a new esophagus was laid inaccurately over this large opening and held in place with three or four catgut sutures, and the mediastinum packed. Under the packings, granulation set in, and the chest became sealed off. The patient unfortunately died, eleven days after operation, of what appeared to be a heart block or a vagus disturbance.

A postmortem wound inspection revealed the left lung fully expanded and adherent to the location of the rent in the pleura. Indeed, the adhesion was so firm that, on removing the flap of skin, the pleura was still thoroughly airtight and the lung completely filled the cavity.

I have had but one opportunity to perform posterior mediastinotomy in a condition other than carcinoma of the esophagus, although I have entered this space transpleurally a number of times.



## REPORT OF CASE

*History*—A P, a man, aged 43, for two months had suffered with pain in the dorsal region, with cough and expectoration and with pain beneath the sternum. There were râles in the right base. Roentgenograms revealed a dense shadow in the interlobar region or in the middle lobe on the right side and over the dome of the liver. There were also shadows at the right hilum. No tubercle bacilli were present in the sputum. The Wassermann blood examination proved negative, three times. Later roentgen-ray examinations revealed a dense mass, apparently in the mediastinum, from the tenth rib up to the fourth, more marked on the left side. There was no fever when I first saw him in the early part of May, 1921. The pain was extreme and was localized in the middorsal region, requiring large doses of morphin for its control. Physical signs at that time indicated râles in both bases and increased voice conduction in the right middle posterior chest. The patient entered the Flower Hospital Private Pavilion, and, May 23, a semilateral roentgenogram, as well as a fluoroscopic examination indicated that the tumor of the mediastinum was continuous with that of the lung and that the greatest density was at the ninth rib, posteriorly. The next day, I operated, Dr. Neuhof assisting. The anesthesia was by gas, oxygen and ether.

*Operation*—The patient lay on his left side in the position of scoliosis. A long incision was made over the right ninth rib, and this rib was subperiosteally resected for about 6 inches (15 cm), with resection, posteriorly, of the eighth and seventh ribs as well. The pleura was easily stripped away from the ribs and from the posterior chest wall, with excellent exposure of the entire posterior mediastinum, but no tumor was found. The mediastinum was packed with gauze, and the pleura at once freely incised and its contents exposed. The lower portion of the upper pulmonary lobe contained a large dusky mass, giving the impression of a neoplasm. A specimen was removed for diagnosis, and about 30 drops of nonodorous pus exuded. We were evidently dealing with an indurative suppuration in the lung, probably secondary to an infected tumor. There was a small elastic bulging mass on the anterior surface of the body of one of the vertebrae, this was punctured with the needle. It bled freely, but no pus was found. The opening in the lung was packed with gauze, which was led out posteriorly. The greater part of the wound was then closed with two pericostal chromicized catgut sutures and a number of interrupted muscle sutures of the same material. The skin was left open and a packing left in the mediastinum. Just before tying the last suture to close the pleura, the lungs were inflated and the chest was closed airtight.

*Pathologic Report* (Dr. Mandlebaum)—The specimen revealed an interstitial inflammatory process, with a purulent inflammation which was evidently superimposed. Nothing was present to suggest neoplasm.

*Course*—No general empyema resulted, although there was some suppuration in the chest wall, and part of the wound was opened wide for drainage. Ten days after the operation, the packings were gradually removed from the mediastinum, and there was only a mild infection. The packing in the lung cavity was replaced by a soft rubber tube. The temperature rarely reached more than 102 F. The pain in the back was completely relieved, and, for a time, it looked as if the man would recover. Indeed, a few weeks later, the wound in the thorax had closed to a small, slightly discharging sinus, when a gradually increasing left hemiplegia appeared, with delirium, and the patient died. Most unfortunately, no necropsy was permitted, but it is probable that he died of a cerebral metastatic abscess.

## COMMENT

This case illustrates how simple a matter it is to make a complete exploration of the posterior mediastinum by this method and how safe from infection such an operation may be, probably because of the ample drainage, for there was no mediastinitis in spite of the neighboring abscess. It is also interesting to note the complete relief of pain in the back which this operation afforded. It was like a true decompression.

Another case, the first to my knowledge in which this method of approach was used in a suppurative mediastinitis, was that of a woman, in the practice of Dr. Harold Neuhof. Here, there occurred high fever and severe dorsal pain, with dulness on percussion in the right lower back running up along both sides of the spine. Remarkable bedside roentgenograms demonstrate first, the value of roentgenography in making a diagnosis of posterior mediastinitis, and, second, the change in the roentgen-ray appearances following the operation and the evacuation of pus from the mediastinum. Dr. Neuhof stated that the procedure was easy and that injury to the pleura was avoided without difficulty. The patient recovered.

## CONCLUSIONS

Although this report of experience in posterior mediastinotomy is limited, I believe it indicates the surgical value of the procedure. As a means of exploration, it ranks with wide intercostal thoracotomy, and is probably more complete than exploratory laparotomy. I believe it will eventually become one of our standard operations and that more successful results will follow earlier intervention. Articles which practically cover the field of posterior mediastinotomy, including the approach to the esophagus, are those by Kirschner<sup>4</sup> and by Rehn<sup>5</sup>. Enderlen's paper is also important.

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4 Kirschner. Oesophagus Chirurgie, *Arch f klin Chir* 24 606, 1920.

5 Rehn, E. Operationen an dem Brustabschnitt der Speiseröhre, *Arch f klin Chir* 57 733, 1898.

# TERATOMA OF THE RIGHT CHEST CAVITY

## REPORT OF CASE \*

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BOSTON

*History*—Jan 23, 1922, a boy, aged 15 years, entered the Massachusetts General Hospital with the diagnosis of dermoid cyst of the right pleural cavity. The father had died of what was probably consumption. Otherwise the family history was negative. The patient had had measles and pertussis. He had never been robust, but otherwise the past history was negative.

During November and December, 1920, that is, fourteen and fifteen months before entrance to the hospital, the patient was rather below par and occasionally complained of pain in the left side of the chest. He played about as usual, however, until January, 1921, when he began to cough a little and had some fever. The local physician thought he had fluid in the chest and sent him to the Newburyport hospital with the diagnosis of "sero-fibrinous pleurisy," where he was admitted, Jan 31, 1921. Examination revealed dulness at the right apex and flatness over all that base below the angle of the scapula. The roentgenographic examination revealed "dulness as high as the fourth space, which did not shift on changing position. The roentgen-ray diagnosis was encapsulated empyema or malignant disease." The patient was discharged February 11, twelve days after entrance, without operative treatment, and somewhat improved.

Subsequently he felt fairly well for nine months, but remained in bed part of the time, and got out of breath if he played much. He believed he gained some weight during this time. He coughed very little, but occasionally there was a little blood-tinged sputum. He had rather frequent gas pains and vomited with indiscretions of diet. In December, 1921, he began to have some pain in the right side of the chest, and, Jan 5, 1922, he was again admitted to the Newburyport hospital. There, examination was much the same as that noted later when the patient entered the Massachusetts General Hospital. The roentgen-ray at that time disclosed "a dense shadow extending to the top of the third rib, showing some increase in size from the previous year." A No 14 catheter was introduced through a trocar, and 4 ounces (118.4 cc) of colloidal jelly was aspirated, with considerable suction. This material contained numerous hairs, from one-half to three-fourths inch (from 12.7 to 19 mm) in length. The report of the pathologic examination of this material made at the Harvard Medical School, was as follows: "Brownish, extremely viscid liquid containing many white flakes, from 1 to several millimeters in diameter, which have a pearly iridescence. These prove to be made up of keratinized epithelial cells. There are also many hairs free and embedded in the epithelial scales. Diagnosis: Material from dermoid cyst."

About two weeks later Jan 23, 1922, he was admitted to the wards of the Massachusetts General Hospital without any appreciable change in condition.

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\* Read before the American Association for Thoracic Surgery, Washington D C, April 29, 1922

*Examination*—This revealed a rather underdeveloped and distinctly under-nourished boy of 15 who did not appear to be more than 11 or 12. The thorax showed marked asymmetry, the left side of the chest being thin and flattened, while the right side was rounded and bulging, the bulging being much more marked at the costal border than at the apex, and much more noticeable in front than behind. The right side of the chest was practically fixed on respiration. The



Fig 1—Tumor occupying the right pleural cavity

left lung was resonant throughout, with exaggerated vesicular breathing, while on the right, the entire chest was flat with absent breath sounds, except for a small area at the apex where breath sounds were transmitted feebly. Tactile fremitus and whispered voice sounds were absent everywhere on the right, except at the apex. Cardiac impulse was visible in the fourth, fifth and sixth interspaces on the left. Maximum impulse was seen and felt,

5 cm outside the nipple line. Sounds were normal without murmurs or thrills. Blood pressure was systolic, 95, diastolic, 60. The liver border was palpable, 5 cm below the costal margin in the right nipple line. The fingers of both hands showed moderate clubbing. The toes showed none. Examination otherwise was negative.

*Laboratory Examinations*—The urine and stools were normal. The sputum was small in amount, watery, brownish and contained staphylococci, short



Fig 2—No evidence of expansion of lung, fluid level in the pleural cavity, seventeen days after operation

chained streptococci and diplococci. Blood examination revealed leukocytes, 10,500, erythrocytes, 5,130,000, platelets, normal, hemoglobin, 70 per cent, differential count polymorphonuclears, 74 per cent, lymphocytes, 23 per cent, transitionals, 2 per cent. The red blood cells were normal. The patient belonged to blood Group IV.

*Fluoroscopic Examination* — "The entire right chest, except the apex, is occupied by a dense shadow with an indefinite upper border. The right diaphragm and the costophrenic sinus are both obscured. No fluid level is observed. The heart is displaced to the left. The roentgenogram confirms these findings (Fig 1). Dulness in the right chest extends to the second rib. The appearance suggests an extensive pathologic process in the right chest, involving the lung, with possibly the presence of fluid."

*Operation and Result*—Feb 1, 1922, an operation was performed. It was started under paravertebral anesthesia, but, as the patient soon became restless and hard to manage, gas oxygen was given and the operation completed under this. A section of the sixth rib, measuring nearly 8 inches (20.3 cm) was removed, and the chest cavity opened. A very large solid tumor appeared, and, in order to expose this, the fifth, seventh and eighth ribs were cut across,

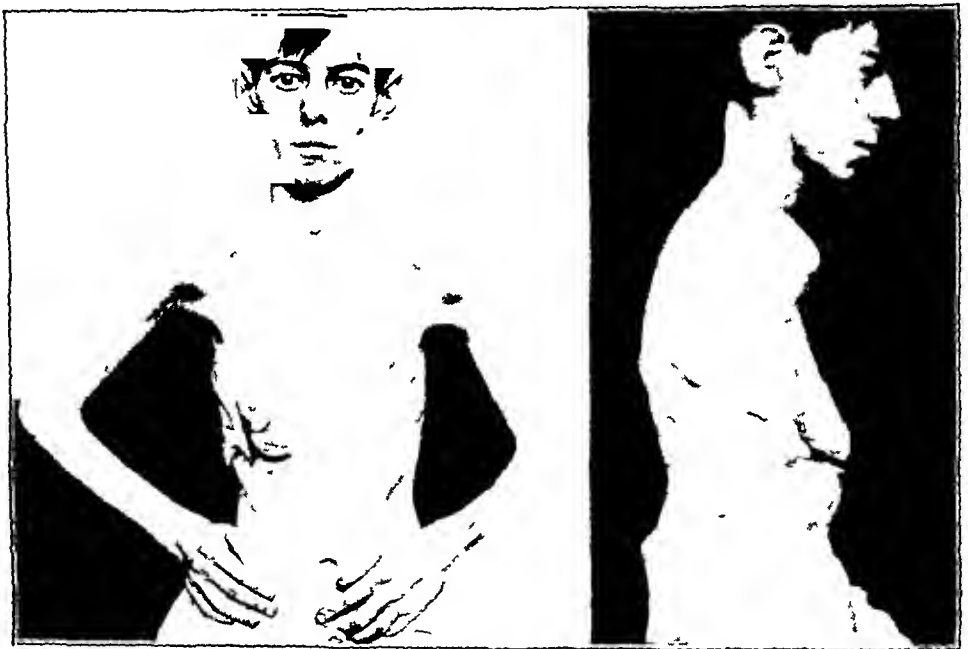


Fig 3—Left, patient after operation, showing drainage tube still in place, right, bulging of the lower part of the chest, the same as before operation

close to the vertebral column. These were spread wide apart, giving an excellent exposure. The tumor extended from the diaphragm to the second rib and was very adherent. The whole right lung was pushed up into the apex of the chest. The tumor was removed, with considerable difficulty, as no definite line of cleavage could be found. There was a pedicle containing several large blood vessels that seemed to have its origin in the mediastinum. After delivering the tumor, the lung was carefully examined. It was little larger than the palm of one's hand, being divided into three lobes. The middle and lower lobes were of about the same consistency as the liver and were a dark brown. The apex of the upper lobe was soft, grayish white and had a very little air in it. The oozing inside the chest cavity was stopped, and the wound sutured tight, with a catheter, which was kept shut off, in the lower end. During the operation, the patient's blood pressure dropped from systolic 95, diastolic 60, to systolic 50, diastolic 30, and the pulse became

slower and slower so that at the end of the operation it was only 50, this probably being due to irritation of the vagus nerve during the removal of the tumor. He was transfused while still on the operating table, although no large amount of blood had been lost. This improved his general condition.

Within twenty-four hours after operation, the patient's pulse gradually increased to 140 and the blood pressure was systolic 85, diastolic 40. Large amounts of bloody fluid were aspirated through the catheter, at first every hour and later every two hours. Nothing taken by mouth was retained during the first three days, and fluids were kept up by means of rectal and intravenous glucose injections. By the fourth day, the patient felt so well that he kept sitting up in bed unless restrained. On the morning of the fourth day, when I

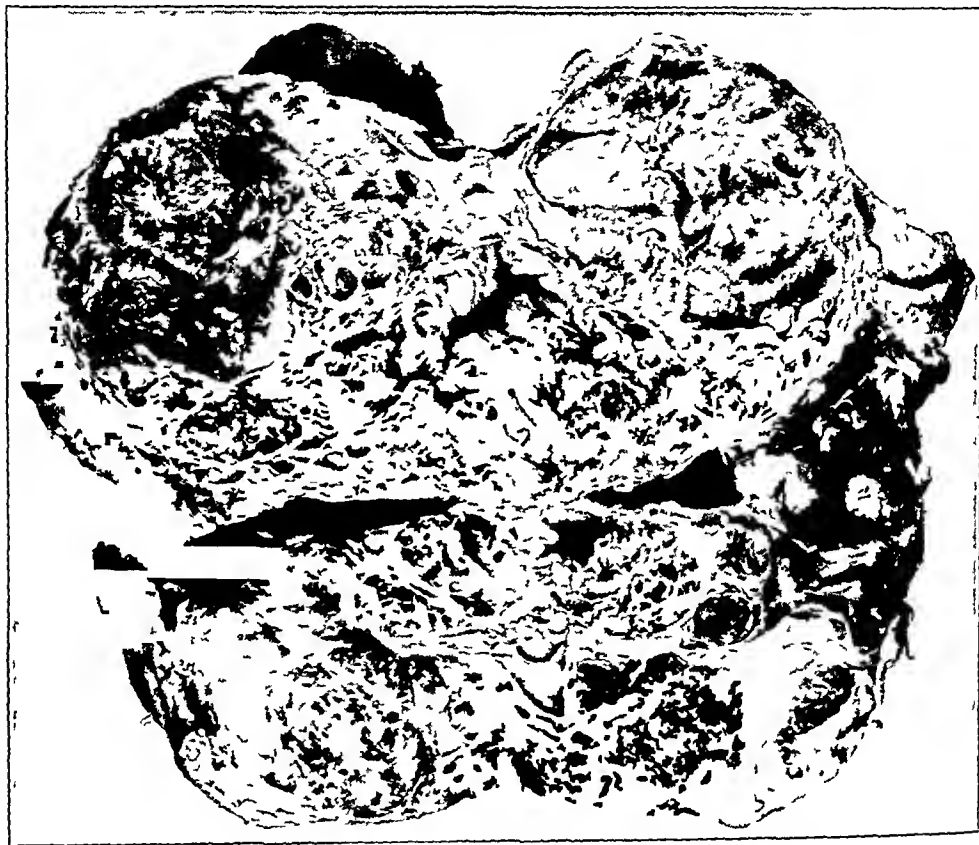


Fig 4—Tumor split wide open

made my visit, he was reading the morning paper. On the eighth day, the catheter was removed, and the sinus was allowed to close, as we could no longer obtain any serum from the cavity with suction. The rest of the wound healed by first intention.

The patient's temperature remained normal for three days, and then the temperature ran a mild septic course, probably from absorption of reaccumulated fluid in the chest cavity. This gave him no discomfort and little constitutional reaction other than the rise in temperature. A roentgenogram, taken February 18, eighteen days after operation, revealed "Considerable fluid in the lower half of the right chest and no evidence of expansion of the lung." The right side of the chest was tapped with a needle and aspirated several times from 2 to 8 ounces (from 59 to 236 cc) of a dark brown fluid being

obtained (Fig 2) This fluid contained practically no leukocytes, and a culture was sterile He gained strength slowly, but continued to have a septic temperature

March 7, thirty-five days after operation, fluid aspirated from the chest was found to contain many leukocytes, and the culture showed staphylococci A No 20 catheter was reinserted in the old sinus at the lower end of the incision, and a large amount of pus was aspirated The cavity was kept fairly clean with irrigations of salt solution, and, although he continued to have a low septic temperature, his general condition improved very much, and he was discharged to his local physician, March 22, fifty days after operation

#### COMMENT

Figure 3 shows the appearance of the patient at the time of discharge The illustration to the right shows the bulging and rounded appearance of the chest, especially at the costal border, as described in the physical examination This still persisted after operation

Pathologic examination revealed a cystic and solid tumor about the size of a large cantaloup, measuring 8 by 13 by 17 cm, and weighing 1,491 gm It had a thick capsule, with redundant folds, containing several nodules about the size of an English walnut These folds evidently represented the collapsed walls of a cyst On section, it was honeycombed with small cysts filled with thick, white, tenacious fluid Some of them showed black pigment There were areas of bony plates and epidermis Some of the cysts were filled with necrotic material, in which hair could be identified Microscopic examination disclosed stratified epithelium, with sebaceous glands and hair follicles, smooth muscle and myxomatous connective tissue, sympathetic ganglion cells and nerve fibrils, tubules suggesting the spinal canal, fragments of deeply pigmented epithelium suggesting retina, tubules lined by epithelium suggesting the intestine, and groups of small tubules filled with eosin-staining material, suggesting the thyroid The diagnosis was teratoma (Fig 5)

Although this boy survived the operation and left the hospital in fairly good condition, it was disappointing to find that the lung showed no tendency to expand At operation, pressure from the gas oxygen machine had no effect on making the lung expand, and breathing exercises following the operation produced no expansion At operation, the only evidence found of air having entered the lung was at the apex of the upper lobe The rest of the lung appeared to be undeveloped and infantile, thus the inability to make it expand was not unexpected

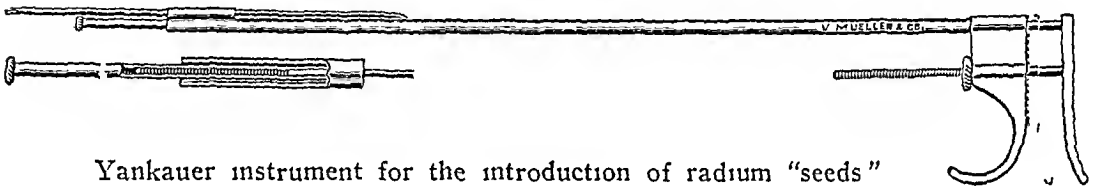


# A RADIUM NEEDLE FOR THE ESOPHAGOSCOPE\*

SIDNEY YANKAUER, M D  
NEW YORK

The instrument here presented is intended for the introduction of glass capillaries containing radium emanations (the so-called radium seeds) into the tumors of the esophagus

In introducing radium seeds into readily accessible tumors, it is customary to introduce the needle and then withdraw it a short distance before ejecting the seed, so that the seed travels in a previously made channel. I have found, after several trials, that the emplacement of the seeds in a tumor of the esophagus through the esophagoscope cannot be accomplished with precision, because the tumor, as well as



Yankauer instrument for the introduction of radium "seeds"

the esophagoscope, are in constant motion, but they do not move together. The position of the instrument cannot be controlled with any degree of accuracy.

To overcome the difficulty, I have constructed an instrument with an adjustable stop by means of which the depth of penetration of the needle can be previously fixed. When held firmly against the tumor with the handle closed, the stylet and the seed are held immovable and the needle is withdrawn, leaving the seed in the channel made by the needle.

In actual use, the introduction of the seeds proceeds quickly and with accuracy.

The instrument is made by V. Mueller and Company, Chicago.

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\* Read before the American Association for Thoracic Surgery, Washington, D. C. April 29, 1922

# SURGERY OF THE MEDIASTINUM, INCLUDING THE HEART AND ESOPHAGUS

## ABSTRACT OF DISCUSSION

DR EDWARD W ARCHIBALD, Montreal, Canada Our President remarked that the treatment of pulmonary tuberculosis was entering a new phase, with Sauerbruch's posterior extrathoracoplasty operation. It is perhaps the only branch of thoracic surgery with which I feel familiar. I can only say with regard to my own experience, which now numbers fifteen cases, that the results have been very gratifying, on the whole. They approximate those of Sauerbruch, with practical cures of from 25 to 35 per cent of the patients. It is our duty individually and as a society to make ourselves familiar with this particular branch of thoracic surgery, because I know of no other branch in thoracic surgery which really promises more, not only that, but there is no other branch of surgery in which our duty from the social and economic point of view is more clear. We all felt last year in Toronto when Dr Lilienthal read his paper on the posterior mediastinal approach and resection of the esophagus that here was a strong ray of light. Heretofore, we all had been pessimistic in regard to resection. I remember going over statistics and finding twenty patients operated on since 1910, and only one living! It seemed that Dr Lilienthal had not only solved the problem, but had devised a means of avoiding the danger of infection. These patients usually died of mediastinitis. By using two stages in his technic, he bade fair to overcome this difficulty, because we all know the defensive power of granulation tissue. Dr Armstrong spoke to me last summer in reference to a case of esophageal cancer and asked me whether I would like to take care of the patient. The woman was middle aged, the symptoms of obstruction had been present for several months, she could still swallow fluids, just enough to maintain a moderate degree of nourishment, but her general condition was good on the whole. She was treated with preliminary irradiation. Esophagoscopy had revealed a cancer just above the arch of the aorta, quite a little higher than that in the successful case reported by Dr Lilienthal last year. It was obvious that we had to do something. I could not agree with Dr Lilienthal that a primary gastrostomy was unnecessary. It seems to me that a primary gastrostomy is advisable. You have to get these patients into better condition. I performed a gastrostomy, and, after waiting about three weeks, the patient was in a fair state of nutrition and I proceeded with the operation. I removed two ribs, the sixth and seventh, bringing the scapula upward and outward in order to give myself more room. Dr Lilienthal says it is not necessary. I dare say it is not. I went in from the right side. I felt that I would not be bothered by the pericardium and that I would have more room. The first thing I discovered was that the pleura was difficult to separate. Dr Lilienthal tells us this morning that it is because one does not go about it in the right way. I dare say that is true, but I cannot see just how I failed to go about it in the right way. I found great difficulty in separating the thin pleura without tearing it. Wherever I worked, it seemed so adherent that I had to proceed with the greatest caution. This was particularly the case when I reached the spinal column where it tore in several places. I had the patient under positive pressure. I am sure I tore through the pleura in places where

it was difficult to see, and, as a matter of fact, although I repaired everything, as I thought, I ultimately caused some pneumothorax which was sealed by positive pressure during the operation but which made itself evident after operation. Then came trouble by reason of the adhesions of the tumor itself to the posterior mediastinum. I separated the adhesions with difficulty. I cannot say how much the adhesions were due to radium and how much to the tumor. I had no trouble from the vagus, and there was no particular shock. I was able to isolate the tumor and to excise it. It was a hard growth, about 1 inch (2.5 cm) in length. I was able to feel the esophagus with the stomach tube quite easily. Difficulties arose after the operation. Since the skin flap was long, it became gangrenous at the edge—about one-fourth to one-half inch from its tip. Symptoms of moderate pneumothorax, evidenced by slight mediastinal flutter, were obvious. They were quite certainly due to tearing of the pleura, which had not been sutured. Infection developed, and the patient died on the sixth day, of what I consider to be a mediastinitis proceeding from infection and gangrene of the flap, combined with a partial pneumothorax on the right side. Such was the result! Now, then, to summarize. The points that I should like to make are that the dangers are still there, I believe. The great optimism with which we welcomed Dr. Lilienthal's paper should be modified, not with Dr. Lilienthal as the operator, but with me as the operator. The difficulty of loosening the pleura is still there, to my mind. I cannot see how "the pleura just falls away." I have seen cases in which it falls away, but it does not always do so. The danger of infection is still there. In order to avoid it, I made the flap just a trifle too long, longer than necessary. I believe one should go a little deeper and include the deep fascia and muscles. If you include the muscles at the base, with the deep fascia, I believe, perhaps, that feature would be minimized. The high situation of the growth did not seem to offer any appreciably greater difficulties to exposure than the lower situation of the growth. As I said, I found no particular vagus effects. These cases are different from those in animals. We have listened to Dr. Fischer's paper with great interest. Experimental work in animals is comparatively easy. In the human being, we shall always have adhesions which cause a great deal of difficulty. The operation itself was not particularly shock producing, there was never any moment in which I was afraid. I merely present the report as a contribution to the subject, pointing out the difficulties I have met. I, nevertheless, still believe that this method is the only rational method for such cases and do not wish this report to be taken as a deterrent. It will not be a deterrent to me, but, nevertheless, I believe we should be prepared for a little more difficulty than Dr. Lilienthal led us to expect in his paper this morning.

DR. LEON T. LEWALD, New York City. I have had an opportunity to study roentgenologically four cases of mediastinal tumors, resembling closely the type described by Dr. Whittemore. My four cases, curiously enough, were all on the left side. Dr. Whittemore's happened to be on the right. The first case was thought to be an aneurysm, but, after prolonged study, we could not detect expansile pulsation, we could distinguish a slight separation from the heart and aortic shadows sufficient to make us believe it did not originate from them, although closely attached to the pericardium. This patient was not operated on. We watched him for about a year. The tumor increased slightly in size, or at least it did not increase materially, as the aneurysm would have been expected to do. We lost sight of the patient, until two years later, when on looking up the history, the outcome of the case was found to be as follows:

The patient had a spontaneous evacuation of the contents of this probable cyst. At the time we saw him he was at St. Luke's Hospital, and two years later in the Presbyterian Hospital, with what was supposed to be influenza. He had a violent attack of coughing, and rather thick material was coughed up. The nature of this material, unfortunately, was not definitely determined pathologically. The man made a complete recovery, and, when we heard from him two years later, he was absolutely well. We believe it was a tumor of this character spontaneously evacuated. The second case was in a boy of 19. The shadow apparently represented a tumor of a similar nature. This young man we observed for three years, and the tumor increased in size, coming almost to the surface of the chest. At that time, we hoped to have him admitted for an exploratory thoracotomy. He, however, was one of the boys about the streets of New York and was not very faithful about returning. I have no further record of his case. The increase in size of the mass in a boy, 19 years of age, was of considerable interest, and would, I think, fit in with this type of tumor, if it were a dermoid. The case is of further interest because of the constantly increasing size, which would render extirpation necessary. The third case is another one of the same type. The tumor was on the left side. That patient is alive after nearly four years, and the exact nature of his condition is a question, but I believe it belongs to this class of mediastinal dermoid. Among other mediastinal growths, referred to by Dr. Matas, I should like to call attention to a case of lymphosarcoma with exceedingly rapid growth in a child, 9 years of age. I believe it belongs to the group of cases which Dr. Matas has discussed so brilliantly, with regard to whether or not temporary relief can be secured. This patient was under observation for six weeks before death. No procedure was of any avail. In the more benign types of tumor, such as Hodgkin's disease, radium or roentgen ray can be used as a diagnostic measure, by reason of the therapeutic effect, while, on the other hand, true infiltrating malignant growths which extend out along the paths of least resistance show little if any response to roentgen-ray or radium therapy. Although it is true there is some temporary relief, that is about all that can be expected in this type of malignant growth of the mediastinum. In regard to Dr. Fischer's paper, it so happens that I have under observation two cases of thoracic stomach, one in a child and one in a woman, 62 or 63 years of age. Both of these cases are exceedingly interesting in relation to the type of operation he has depicted, of drawing the stomach up into the chest. These two individuals are comfortable and well. The child had to have a palliative operation through the diaphragm for an obstructive lesion. I believe this type of stomach is developed above the diaphragm, while, in true hernia, the stomach is actually formed below the diaphragm and then passes up into the chest cavity. One other case of thoracic stomach has been reported in Chicago. The author states that, in his opinion, it is possible for the stomach to develop above the diaphragm. Shortly after seeing this child, we saw the case in the woman over 60, in whom the stomach was entirely behind the heart, the esophagus entering the stomach above the diaphragm. In a true hernia, the esophagus must come from below. If one makes a differential diagnosis between intrathoracic stomach and hernia, it is made by the way in which the esophagus enters the stomach. The point is that these two individuals are in robust health, one a young subject and one old, with their stomachs entirely in the chest cavity.

DR. FRANZ J. TORFK, New York City. I will confine my remarks to carcinoma of the esophagus. Dr. Fischer and many others have pointed out that

thus far the results of surgical treatment of carcinoma of the esophagus are not very encouraging. To improve the results, there are two factors necessary, one is the improvement and simplification of the technic and the other is the recognition of the cases at the time when they are still favorable for operation. Now, as for the first of these requirements, many of us in this Association have done our best to improve the technic and to simplify it. I am sure we have worked very, very hard. I cannot say that the general medical public has come up to the second requirement, namely, the recognition of carcinoma of the esophagus at a time when it is still operable. We operate on practically all patients that are sent to us, and it has been our unfortunate experience that many of the cases are so far advanced that the tumors either crumble under our hands or are adherent to the connective tissue around, having worked through the walls of the esophagus, instead of affecting only the mucous lining, to such a degree that often both pleurae are affected, and extirpation offers an enormous number of difficulties and is often unsuccessful. Dr. Lihenthal used a comparison which I thought was very apt, when he likened the condition to appendicitis, thirty-five years or more ago. No patient with appendicitis was ever operated on unless he presented a large mass, easily made out by dulness on percussion, consisting of a large abscess. At that time the voices that decried any operation on an appendix that was not perforated were very loud. At times, a surgeon who suggested operating on a nonperforating appendix was looked on almost as a criminal, and, at the present time, surgery of the esophagus is in almost the same antiquated state. If a patient is still able to nourish himself by swallowing soft food, and is not losing flesh, even the suggestion of performing a radical operation for carcinoma of the esophagus is looked on as criminal. It is my hope that we will advance in this branch of surgery in the same degree that we have advanced in the surgery of the appendix. The misfortune is that the diagnoses are not made early enough. The trouble is that the esophagoscope is not used early enough. If there is the slightest suspicion of trouble in the esophagus, an esophagoscopy is decidedly indicated. For example, if there is some obscure condition in the lower colon, we do not debate about performing a sigmoidoscopy, we consider it our duty to do so. We have not yet gone so far as that in the matter of carcinoma of the esophagus. Dr. Robinson, in his presidential address, made the remark that physicians will find a good deal of trouble in getting a surgeon to perform their thoracic work. I was somewhat astonished at first when I heard this, but I believe he is right. It is really true, and the reason is that the practitioner seeks the surgical advice of a person who has paid no attention to thoracic surgery and consequently will have different ideas from those which we are expressing here. If these physicians would apply to any one of this assemblage, he would find no difficulty in receiving surgical aid for his patient. This very apt remark of Dr. Robinson's has two sides, the other side being that we thoracic surgeons find a great deal of difficulty in getting physicians to send their patients to us. I am sure you have all had that experience, and, as I said before, our diagnosis should be made early. To give one instance in relation to this subject, take the symptom of the hysterical globus in the neck, in which there is difficulty in swallowing, called hysteria. If that symptom occurs in a young person, 16 or 20 years of age, all right, call it hysterical globus, but if this symptom occurs in a person, 35 or 50 years of age, the person who passes it off as an hysterical symptom is not doing his duty. It is his duty to have esophagoscopy employed and to find out whether the hys-

terical globus is not simply a distant symptom of a deep-seated lesion. If we find these deep-seated lesions earlier, at a time when only a portion of the mucosa, or muscularis, is involved, and the outside of the esophagus is still perfectly free, the likelihood of infection is small, the likelihood of bleeding is small, and our results will be a great deal better than they are at the present time. I believe that it is very fortunate, as far as the technic of the operation is concerned, that we are not all working along the same line, that we are working in different directions. By doing so, we can compare notes, and we should not—if we consider that perhaps one line of attack appeals to us as being something new and different—at once discard the older methods. They may be all right, and a great deal has been said of the extrapleural attack. At present, I admire it, and it may be the better one, but we do not know. We should not give up the transpleural method by any means. Some should work by the transpleural and others should work by the extrapleural method. Which of the two is going to have the final say, we cannot as yet determine. The main thing is that we inspire our medical friends to make early diagnosis and use the esophagoscope earlier.

DR EVARTS A GRAHAM, St. Louis. In the first place, concerning the presentation of the subject of anterior mediastinal tumors by Dr. Matas, I was very much interested in his discussion and presentation of the question of decompression of these tumors by splitting the sternum longitudinally, because recently I have had an experience of a similar nature. A man had symptoms of dyspnea over a period of about three months, which seemed to begin with an attack of what was thought to be influenza. He was a traveling salesman and observed the first symptoms while on the road somewhere. He was brought to St. Louis and went to a different hospital from the one where I generally work. There a diagnosis of left-sided pleural effusion was made, and 3,000 cc of bloody fluid withdrawn, said to contain pure culture of the bacillus of Friedlander. Following this, a large shadow was revealed by the roentgen ray, which was thought to be an enlarged pericardium. The man's dyspnea was only partially relieved by withdrawal of the pleural effusion. Twelve different attempts were made to aspirate the pericardial cavity, all without success. I was asked to see the man in consultation. When I saw him, he was in most extreme orthopnea and cyanosis, his fingernails were almost black. He had been able to assume only a forward reclining position for two weeks. He sat up in bed, leaning forward over a small table, which was the only way he could live. On the basis of the shadow revealed by the roentgen ray, which showed an irregularity on the right side of the pericardium in addition to an enlargement of the axillary glands on both sides, which I think Ewing called attention to first, I made a diagnosis of probable mediastinal tumor. The man was very evidently near death from dyspnea. I advised immediate decompression of the anterior mediastinum for the purpose of exploration, hoping that decompression might give some respiratory relief. He was accordingly taken to the operating room, and, under local anesthesia, we split the sternum longitudinally from top to bottom, using a chisel part of the time and part of the time a rongeur. To our surprise, there was no particular gaping after splitting the sternum. The operation was performed under the most extreme difficulties, it was like lying on one's back in the street to repair an automobile from below. The patient had to lean forward during the entire operation. We combined, with the operative procedure, inhalations of oxygen. After splitting the sternum, the dyspnea was not materially relieved, but I found a huge mediastinal tumor which I diagnosed

as probably a lymphosarcoma. The patient died one-half hour after operation. Only a limited necropsy was permitted, but we found a lymphosarcoma which completely surrounded the trachea and enlarged bronchi and also encased the heart. This represents another case of the type of tumor which Dr. Matas mentions, from which we cannot expect decompression to afford very much relief—a constricting tumor, one which not merely causes pressure. I believe that the immediate cause of death was a failure in oxygen. It seemed so to us at the time. There was no proper equipment for intratracheal or intrapharyngeal administration of oxygen. We tried to give oxygen through an ordinary nitrous oxid machine, but it was unsatisfactory. The oxygen supply finally gave out. I believe if these things had been taken care of before, the patient's life might have been spared, at least as long as that of Dr. Matas' patient. One thing I wish to speak about is the question of thoracic stomach, which Dr. LeWald brought up. About a year ago, in the St. Louis Children's Hospital, a patient, 5 years of age, was brought to Dr. Clopton, with a discharging sinus from the left chest and a history of pneumonia about six weeks previously. He had been operated on for empyema by his local physician and had been left with a discharging sinus. We found, however, that this sinus was not a pleural sinus, but extended into the stomach, which was in the pleural cavity. The question arose whether the child ever had empyema, or whether, during the operation for empyema, the diaphragm had been injured, resulting in a diaphragmatic hernia. This aroused some interest on our part, and we found two other cases in the literature in which apparently a diaphragmatic hernia of the stomach had been operated on, under the supposed diagnosis of empyema. It is not an unnatural diagnosis to make without a roentgen-ray examination. If a patient with a thoracic stomach happens to have pneumonia, a needle is put in and material obtained which looks a little like pus, it is not at all surprising that a diagnosis of empyema should be made in such a case. The interesting thing in the case I mentioned is that the child was treated conservatively in order to clear up a considerable amount of infection which came from burrowing of the infection beneath the skin, so that there were two or three sinuses, instead of the original one. The sinus closed spontaneously. The child gained rapidly in weight, and he has now no symptoms whatever from the thorax. No attempt has been made to repair the supposed diaphragmatic hernia, and the child is without symptoms. One other point concerns the handling of carcinomas of the esophagus, particularly by the method suggested by Dr. Lihenthal. If the principal danger in this procedure, and in procedures on the esophagus, is infection of the mediastinum, then, of course, any method which eliminates infection would supposedly be one of the best. Dr. Lihenthal, I believe, in his two-stage method advocates the use of a cuff of skin. That is a very ingenious device, but, nevertheless, the skin always contains bacteria, therefore, there is always danger of introducing bacteria into a denuded mediastinum by such a procedure. For this reason, I would call attention to some experimental work on dogs done in our laboratory by Dr. Allen (*Ann Surg* 76 157 [Aug] 1922). Although it has not been applied to human beings, and, therefore, may not be so satisfactory as in dogs nevertheless, it gives promise of offering a satisfactory method. The method consisted in using a double flap of fascia lata around the esophagus. The first stage consisted of isolation of the esophagus and the placing of a double cuff around the portion to be excised. Two weeks later, the portion of the esophagus to be excised, with the inner layer of fascia lata could be readily removed. The outer layer of fascia lata had become

vascular, could be promptly sutured over, and, in practically every instance in a series of thirty-one dogs, survival took place, without any evidence of infection. The fascia lata forming the cuff later becomes lined with epithelium, by both upgrowth and downgrowth, and, though there is some tendency to stricture formation, in dogs at least it seems to do away with the danger of infection of the mediastinum.

DR KARL SCHLAEPFER, Baltimore. I had the opportunity, a year ago, of seeing Dr. Lilienthal's case in New York. I was much impressed by his method. In regard to his operation, I wish to make two suggestions which I failed to find in different articles dealing with this new operative procedure, which seems to me to offer a very bright outlook in thoracic surgery. One is preliminary gastrostomy, or, if the surgeon intends to use the stomach for his plastic work, perhaps jejunostomy. I had a wide experience with jejunostomy during my stay in Vienna with Professor von Eiselsberg. By using jejunostomy as a preliminary procedure, we have the whole stomach at our disposition for further plastic operation within the thoracic cavity. By performing a gastrostomy, or jejunostomy, we avoid mechanical irritation of the tumor. In about ten necropsies in cases of cancer of the esophagus, I was impressed particularly by the fact that the growth is partly due to inflammatory reaction. This reaction makes it difficult for the surgeon to decide whether the case is suitable for radical operation or not. By performing a preliminary gastrostomy, we can avoid the passage of any food through the esophagus, and we can reduce the size of the tumor by avoiding any further mechanical irritation of the growth which will lessen the inflammatory reaction around the tumor. I might compare this procedure with a similar one used in cancer of the rectum, where, by means of a preliminary colostomy, we see the growth diminish in a short time. A very helpful therapeutic procedure would be the combined use of radium, in the form of needles introduced into the tumor, and the roentgen rays for destroying tumor cells in the neighborhood of the growth and in the regional lymphatics. By using this procedure, we might find, after a short time, a well circumscribed tumor, the pleura perhaps thickened, and, in this way, the patient well prepared for the second operation as suggested by Dr. Lilienthal. These two procedures, it seems to me, would open a new prospect.

DR ROBERT T. MILLER, Baltimore. At the risk perhaps of boring the members of this association, I should like to speak of some experimental work in which we have attempted to devise a method of esophageal resection and suture. Through the courtesy of Dr. Halsted, this work was carried out in the Hunterian Laboratory of the Johns Hopkins Medical School during the fall and winter of 1921-1922. In a general way, the plan adopted was to free the diaphragm from the stomach at the cardia, to draw the stomach into the left pleural cavity, to resect a portion of it in its lower third, invaginating the cardiac end of the stomach and implanting the end of the divided esophagus in the wall of the fundus of the stomach. The method of suture used was, in principle, the "blind-end" method reported by Dr. Halsted (*Ann Surg* 75:356 [March] 1922), though the technic he described was altered in certain details. The result of suture by this method was rather surprising, since, contrary to the experience rather generally reported heretofore, the suture in our work did not tear out. This method of anastomosis resulted in an opening which functioned. The series represents hardly twenty dogs as yet and perhaps four dogs have died after operation, but when the animal survived, the operation resulted in a functioning anastomosis. We, therefore, believe that esophageal suture can be carried



out in the pleural cavity of a dog with a rather certain degree of success. In 1920, Kirschner, in the *Archiv für klinische Chirurgie* made a proposal to adopt the same scheme, though in a rather more elaborate fashion. His proposal was to divide all the blood vessels going to the stomach, except those coming in from the right end. A stomach so mobilized could then easily be drawn to practically the superior limit of the pleural cavity. Before we found this article, we had started with just this idea, knowing nothing about his work. It is surprising how much of the stomach one can draw up into the chest. If one adopts the proposal of Kirschner with reference to the division of blood vessels, it is perfectly possible to dislocate the entire stomach of the dog into the chest, suturing the diaphragm to the pylorus. However, we found in dogs that so extensive a division of the arteries supplying the stomach would not be tolerated. A division of the coronary, vasa brevia and left gastro-epiploic arteries results, within four or five days, in a perforating ulcer of the stomach wall in more than 75 per cent of the cases. This condemns the method. Division of the coronary and vasa brevia arteries alone appears to leave a perfectly viable stomach. If one divides the two arteries mentioned, it is possible to dislocate the stomach far enough into the chest to replace practically the entire thoracic esophagus. In the dog, then, we have a successful method of suture and a feasible method of mobilizing the stomach. It remains to be seen whether one can replace the entire thoracic esophagus in this way, and experiments are now being carried on with this object in view. Is this method applicable to man? Unfortunately, we cannot tell, since we have had no opportunity to apply it. The possibility of suture of the human esophagus has been doubted because of the supposed absence of a submucous layer in its wall. We believe this is not true, and offer as evidence the fact that we have found a double suture line of silk, placed in an esophagus freshly removed from the human cadaver, able to withstand a pressure of about 6 feet of water before there is leakage of either air or fluid. Such security is well beyond any clinical demand. Secondly, we have found that, by stripping the mucosa from the lower part of the human esophagus, a layer of submucosa can be demonstrated strong enough to break a fine intestinal suture needle. By analogy, then, one might reasonably infer that the human esophagus will lend itself to suture. If it is possible to develop a technic for resection of the esophagus and restoration of that tract by this method, we will have made perhaps a start toward converting the present hazardous and unsatisfactory operative treatment of esophageal carcinoma into a procedure analogous to intestinal suture and possibly approximating it in simplicity. The result of attempts to restore the destroyed esophagus by constructing an antethoracic canal have been of doubtful value, inasmuch as but one case has been reported as completed within three months, and most of them have required from six and a half to nine months, the prolonged struggle with the resulting fistulas having been completed usually hardly before recurrence has made itself evident. I hesitate to present so brief a summary of this work, and, especially, since we have as yet not been able to attempt it in man. So far as experimental evidence goes, Dr. Andrus and myself feel greatly encouraged in the belief that ultimately the operation will be shown to be feasible.

DR JOHN L. YATES, Milwaukee. I had the privilege, during the last week, of seeing Dr. Miller's work, and I became convinced that he is finding the solution of the problem of excising the lower end of the esophagus, if not the middle portion as well. Like Dr. Matas and Dr. Graham, I have attempted mediastinal decompression. My result was thirteen times inferior to that of

Dr Matas since the patient lived for twelve hours. Usually, if there is indication for mediastinal decompression, there is advanced periadenitis with adhesions, and these conditions make decompression impossible. On the other hand, patients so affected can be carried along for months, with far less distress, under proper dosage of roentgen ray. Dr Whittemore is to be congratulated on the excellent work he is doing. He brought out a point of clinical significance when he spoke of "liver-like" consistency in the lung above the tumor. We were forced to the conclusion that after gunshot wounds such carnified lung is a menace in the chest and will never function again. If this is true, immediate resection of carnified lung is indicated, even if resection amounts to lobectomy. There was an old superstition that sunlight and scar tissue were the chief factors in controlling tuberculosis. It is now recognized that the most important element is local resistance, the result of which is the formation of scar tissue. In combating disease, this local resistance is of the utmost importance and depends directly on an adequate blood supply. Physiologically, it is desirable not to cause the formation of scar tissue which reduces the blood supply, but to increase the blood supply with the subsequent formation of scar tissue, if such is necessary. Thus it is that phrenotomy, which causes true diaphragmatic paralysis, leads to a maximum blood supply, and hence to the provision of the best opportunity for spontaneous healing.

DR CARL A. HEDBLUM, Rochester, Minn. We had one case at the Mayo Clinic in which I split the sternum longitudinally. There was considerable spreading of the cut edges, but the symptoms were not appreciably relieved. The patient lived for a few days after operation. The mediastinal tumor proved to be lymphosarcoma. I was much interested in Dr Whittemore's case report. Recently, we have had two cases of dermoid of the thorax. One was not diagnosed, but was found at necropsy. The patient came to the clinic, presenting a typical picture of exophthalmic goiter. While receiving preliminary treatment for this disease, she developed symptoms of pleural effusion. Aspiration yielded a canary yellow fluid which was sterile, but a culture from a specimen obtained later showed pneumococci. Hypochlorite irrigation failed to diminish the size of the cavity or to sterilize it. In the meantime, a double ligation was performed, the crisis occurred, and the patient died of hyperthyroidism. Necropsy revealed a dermoid of the diaphragm, with two balls of hair in the pleural cavity. The second case was that of a man who first came to the clinic several years ago with symptoms of pulmonary abscess. He refused operation, and a spontaneous perforation occurred on the anterior chest wall. At operation last winter, a dermoid of the pericardium was found, with surrounding abscess cavity which had perforated into a bronchus. The dermoid tumor was covered with a sparse growth of short hairs, and there were masses of hair free in the abscess cavity, which was lined with squamous epithelium. The dermoid was removed, and the cavity walls and bronchial fistula were cauterized. The patient made a good recovery. Regarding the retropleural approach to the esophagus, those familiar with the literature will recall that the operation has been repeatedly described and it has also been performed on the living patient. The relative merits of a right-sided and a left-sided route have also been discussed with advocates for each. I have tried both, and, from my limited experience, I favor the right-sided approach. Here the aorta is not in the way and in the region of the middle portion of the esophagus the arch of the azygos veins acts as a guide to the esophagus. After this vessel has been doubly ligated and cut,

an unobstructed access is afforded to the region of the esophagus, which is inaccessible from the left side, owing to the arching of the aorta over it. Unfortunately, the cases I have had have been inoperable in the sense that the tumor had infiltrated the tissues surrounding the esophagus. In one such case, I tore the esophagus in liberating the tumor. The patient died on the sixth day, of mediastinitis. A second patient lived twenty days and died of leakage, caused by cutting through of the sutures in the lower stump. During the resection, I encountered a milky fluid which I thought was pus. I, therefore, did not use so much precaution in suturing the stump as I otherwise would have done. Later, I discovered that this fluid was not pus, but chyle from a tear in the thoracic duct. I believe that failures in the past in operating for carcinoma of the esophagus have been due in part to technical difficulties which can be overcome partly at least, but we must operate before the disease has infiltrated the surrounding structures.

DR NATHAN W GREEN, New York City. Regarding carcinoma of the esophagus I should like to relate a personal experience. Last winter I was called to one of the principal hospitals in New York by one of our medical men and by one of our surgeons to examine, with the esophagoscope, two cases of esophageal obstruction. I made the diagnosis of cardiospasm in one case, and this the medical man retained. In the other, I made a diagnosis of carcinoma, and, on this diagnosis, the surgeon operated. He used Dr Torek's approach and stripped off the pleura of the left side from the mediastinum, thereby obtaining a good exposure of the carcinoma. However, to make a long story short, the pleura that was stripped off sloughed, and the patient developed a septic pleuritis on that side and died on the ninth day. The reason for mentioning the case is this. He said, "What shall we do?" It seemed to me that if one could establish an aseptic inflammation in the pleura, so that the visceral pleura might be glued tightly to the parietal pleura before operation, a considerable amount of inflammation in the mediastinum would not then be so disastrous, as there would be no free pleural cavity to contaminate. I suggested to him that if he should operate in another case he should inject "aleuronat" into the pleural cavity, in this way attempting to obliterate the pleural space by a sterile chemical inflammation.

DR WILLY MEYER, New York City. I am sure that every one of us has the feeling that this discussion has been not only impressive, but extremely stimulating. There is still a kind of "lull" in esophageal surgery, principally because the roentgen ray and radium have appeared as factors in the treatment of esophageal carcinoma, and rightly so, perhaps. About three years ago, the late Dr Henry H Janeway of New York told us, at one of the meetings of the New York Society for Thoracic Surgery, that he had had under his care for radium treatment as many as thirty-five cases of esophageal carcinoma at the Memorial Hospital. That was in but one hospital! It is thus easy to see why surgeons at present have comparatively little chance to operate for carcinoma of the esophagus. The principal reason for the lack of confidence in surgery on the part of the medical man seems to be that surgeons cannot yet present to the general practitioner "a series" of patients with carcinoma of the esophagus treated and cured by operation. Dr Meltzer once said, "Give the surgeons at least the chance to do the operation, then they will gradually develop the various methods." As has been frequently stated, we all have to continue to work for the early diagnosis of esophageal carcinoma. I fully concur with Dr Torek's view, namely, "that we ought to work transpleurally as well as by the mediastinal approach in operations for

cancer of the esophagus" Surgeons approach the kidney from the front and from the back Let us always remember that we are at the very beginning of this chapter of surgery, and that, therefore, it will take some time before we shall be able to determine what is best in the various methods The transpleural approach certainly gives wonderful access, one can see and find out from the start whether or not the case is still operable In one instance, the local condition at the seat of the esophageal tumor seemed to me to permit of radical removal, yet we found metastatic deposits in the lung This, of course, could never have been detected when approaching the esophagus by the posterior mediastinal route The success in the transpleural resection is, it seems to me, principally a question of correct airtight drainage Moved by the pitiful appeal so commonly made by these patients with malignant esophageal stricture to give them back the ability to swallow, I was led, in two instances of inoperable carcinoma, to divide the esophagus above the stricture, inverting the distal stump and transposing the proximal portion extrathoracically Both patients stood the operation well and lived for from seven to eight days One of them died of pneumonia, in the other, the necropsy proved that, with typical airtight drainage employed in the after-treatment, the lower portion of the lung had become adherent to the chest wall, while, within the upper part of the pleural cavity, there was some accumulation of fluid, septic material, which took the life of the patient I only mention these cases because we learned from them that it is the "proper drainage of the chest" which seems to decide the patient's fate Again let me emphasize that we are at the beginning of this chapter of surgery I, therefore, believe that the transpleural, as well as the posterior mediastinal, approach should be further tried in this class of cases Gradually, we shall learn when one is indicated and when the other But we certainly should not hesitate, but continue to report our experience for the benefit of all interested, even if we did not succeed in saving the patient's life We should state in the literature what operation and observation of the case during the after-treatment have taught us After all, it seems to me, that at this very moment the final effect of radium and roentgen-ray treatment is a question of paramount importance There are a few cases on record in which, it is claimed, radium caused an esophageal carcinoma to disappear, and the patients are alive today On the other hand, we have Dr Torek's patient alive today, eight years after operation We have, in his case, the clear proof that a patient operated on at a comparatively early stage can recover from the operation and remain cured Therefore, I say, what is important at the present moment is a response from the men who treat these patients with radium and the roentgen ray, stating what they have accomplished up to date Then we can compare notes It certainly is a real pleasure to hear how members of our Association are pushing ahead, and, in spite of roentgen ray and radium treatment, are working at the resection of esophageal cancer I had a case of tumor of the mediastinum which, to me, was extremely interesting The patient was operated on three years ago, when the American College of Surgeons met in New York The anesthetist had great difficulty in introducing the catheter for intratracheal insufflation Bloody mucous oozed out of the catheter before operation was begun We found a large cystic tumor directly above the diaphragm, which proved to be a cold abscess from a tuberculous mediastinal lymphatic gland The patient died with the temperature rising to 107 F on the second day after the operation Necropsy demonstrated that death was due to a most acute pneumonia During the discussion here today

the topic of diaphragmatic hernia was touched on. Lately, we had a baby boy, aged 16 months, at the hospital, with a congenital diaphragmatic hernia. He had entered with the diagnosis of pneumonia, but, on observation, it became evident that we had to deal with a typical intestinal obstruction, and that a large portion of the intestinal tract was within the right chest. Purgatives had brought no response. Although we were almost sure from the clinical and roentgen-ray examination that we had to deal with a congenital diaphragmatic hernia, we decided, after careful deliberation, to open the abdomen first, in order to determine the correctness of the diagnosis. When I first saw the little boy, he had been in the hospital for three days. At first, there had been vomiting, but, during the last twenty-four hours, this had ceased. We opened the abdomen and found pus. At the lesser omentum we saw pus shining through. A very large liver filled out the dome of the diaphragm completely, a hernial aperture was not visible. In the depth, we found a part of the transverse colon, like a small band, but we could not move it. The coils of the jejunum and ileum were partially in complete collapse. While following the small intestine from the upper jejunum downward in order to find the cause of an obstruction in its course, the child vomited and died from suffocation, the result of fecal drowning. All our efforts at resuscitation proved of no avail. We continued searching and found a large hole in the diaphragm to the outer side of the upper pole of the right kidney. Having meanwhile obtained permission for a wound inspection, we enlarged the diaphragmatic hernial aperture and withdrew from the chest the lower ileum, the ascending, and part of the transverse colon. In the middle of the latter, there was a gangrenous area which had perforated. The lung was completely compressed and atelectatic, close to the spine. I learned important lessons from the case, which I shall never forget. First, in the future, I shall, even in babies and in the absence of vomiting, wash the stomach before operation, if there is the slightest suspicion of an intestinal obstruction. Secondly, in the case of a suspected diaphragmatic hernia, I shall enter the thorax first. Had I done this in the present case, we should have been able to make a definite pathologic diagnosis "during the life of the patient," and, if the purulent infection present had proved not to be of too severe character, I believe there would even have been a chance to help the little patient by the operation after the thoracotomy, in spite of the gangrene of the colon. The case shows that such patients can, for a time, be perfectly well, with functioning of the small and large intestine, although one lung is completely compressed. The question is, Should they be operated on? I believe they should, if they can be taken in time.

DR RUDOLPH MATAS, New Orleans. Anterior median thoracotomy by complete longitudinal division of the sternum for thoracic decompression was performed in a case of mediastinal lymphosarcoma, characterized by progressive asphyxial phenomena. A decompression operation, performed for purely palliative purposes, thirty-six days after a preliminary tracheotomy, with permanent intubation down to the bifurcation, had failed to relieve the patient's increasing distress. Temporary relief was obtained during the operation, followed by cardiorespiratory exhaustion and death, four hours after the intervention. The clinical observation, with necropsy findings and commentaries on the value of midsternal decompressive thoracotomy as a palliative measure in inoperable mediastinal tumors will appear in the original paper to be published later as a separate contribution to the transactions. This discussion has, at least, brought out three unpublished cases. They all con-

firm the impressions gathered from the literature and from my personal experience. The idea of decompression as applied to intrathoracic neoplasms has no analogy in the principle of decompression for the relief of intracranial tension. This is particularly true of the malignant growths of the mediastinum, which not only compress, but penetrate, infiltrate and block the respiratory passages. All such cases have proved fatal in spite of sternotomy. The three new cases of complete longitudinal median sternotomy, so interestingly reported by Drs. Graham, Yates and Hedblom, all point to the same conclusion, namely, the benefits that may accrue to the patient from median sternotomy for decompression in inoperable intrathoracic growths are, at best, only palliative and so ephemeral in duration that they scarcely justify the operative risk and hardship imposed on these hopeless patients. Greater relief can be obtained by the free administration of morphin and other succedanea. If only in this negative sense, I believe some good has come of this discussion.

DR. HERMANN FISCHER, New York City. This subject is so extensive that it is difficult to summarize it in three minutes. I should like to say, however, a few words about the impressions that I have gained from my studies of the subject. In our hospital, it was only natural to follow Dr. Torek's technic on account of the very beautiful result he has achieved by it, and we still believe that the transpleural route as far as exposure is concerned is the method of choice. Kummel, in Germany, Dr. Lilienthal of New York, and others who look upon the transpleural approach as too dangerous and producing too much shock, have now turned to the extrapleural method. Of course, we are still only at the beginning, and we do not know how successful we shall be with this method in the future. It seems to me that in these extrapleural operations we often start extrapleurally and end with an intrapleural operation. It seems that all have not been so fortunate as Dr. Lilienthal in avoiding opening of the pleural cavity. If the pleural cavity is once opened, we expose it to the same dangers as in the transpleural method, but at the expense of room. I grant that the transpleural approach is more formidable. The reflexes from a widely opened pleura are surely not indifferent. The majority of patients are emaciated by the ravages of the disease and the shock of the operation is consequently great. I have no personal experience with the extrapleural approach, and, although I have seen from the pictures Dr. Lilienthal showed this morning that the approach seems adequate, I believe I shall continue to use the transpleural method. In my own work, I have had the misfortune of always receiving far advanced cases, in which the seat of disease was mostly near the bifurcation. In all cases, I succeeded in removing the tumor, but all patients died from shock. I believe the best results will be achieved if the whole esophagus is removed from the thorax, because all endeavors to make a tight suture in the human being have been fatal. How far the method Dr. Miller has suggested will be successful remains to be seen.

DR. HOWARD LILIENTHAL, New York City. The skin flap is not necessary. The operation may be performed without any skin flap, according to Dr. Neuhof, who resected the esophagus in the neck in dogs. Epithelization occurred over the raw surface of the area left by the resection, and the dogs were able to swallow. In man, I believe an esophagus thus resected would probably close up by stricture, though sounding might keep the passage open. An operation for resecting cancer of the esophagus should not be performed if thorough radium treatment has been previously employed because of fibrous adhesions to the surrounding organs. We have had cases of this kind—hope-

less after radium because of the presence of this tough periesophageal fibrous tissue. In cancers of the esophagus in which the patients cough, we must perform bronchoscopy as well as esophagoscopy. One of my patients died, in whom an endobronchial carcinoma existed unrecognized until necropsy. We must operate on sick dogs and healthy men if we are to come to a proper understanding of the relative advantages of surgical procedures. Surgery on healthy dogs cannot predict results of similar procedures in starved and emaciated human beings. In discussing Dr. Matas' paper, I should like to mention two instances in which I have performed longitudinal transsternal mediastinotomy. In one other, I attempted it, but without completing the operation. In the attempted case, the man was dying, and, on account of obstruction to the circulation in the large veins, there was tremendous congestion and so much bleeding that I had to desist. One successful case was that of a retrosternal goiter (Lilienthal, Howard *Surg, Gynec & Obst* 20 589 [May] 1915). Another case was like the case of Dr. Matas. I performed the operation with chisel and gouge. It is absolutely necessary to divide the posterior periosteum of the sternum, and then from  $1\frac{1}{2}$  to 2 inches of separation of the sternal halves will be possible. In cases of lymphosarcoma, the tumors nearly always surround the trachea, very probably because they start in the vestiges of the thymus. In my next case, I intend to cut down to the trachea through the tumor. I believe this can be done with relief of respiratory embarrassment. In my case of tumor (angiosarcoma), the patient lived for twenty-four days after operation and died following severe reactions from injections of Coley's toxins.

# THE DIFFERENTIAL DIAGNOSIS BETWEEN TUBERCULOSIS AND LUNG ABSCESS

A CLINICAL AND ROENTGENOLOGIC STUDY OF TWELVE CASES  
SEEN AT ST LUKE'S HOSPITAL \*

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This brief paper is presented to record our recent experience in this class of cases and to promote discussion of this topic. Twelve cases form the basis of this report. Eight patients were operated on and the diagnosis established, all of these recovered. Four were not operated on for lung abscess, and, of these, three recovered and one died. None of these cases is included in a previous report of ten cases by one of us (N W G) <sup>1</sup>

Following the classic and recent work of Dr Lilienthal<sup>2</sup> and Dr Aschner<sup>3</sup> on suppurative infections of the lung, we have employed the following classification: (1) bronchiectasis, (2) bronchiectatic abscess, (3) suppurative pneumonitis, (4) extrabronchial abscess.

As no resections of tissue were made in this series, we are able to say only that we had to deal with a suppurative cavity, in almost all instances, discharging pus through a bronchus.

It is probable that extrabronchial abscesses do not long persist as such, but sooner or later become connected with a bronchus, so putting themselves into Group 2 of the foregoing classification. Then they become bronchially discharging abscesses. In Cases 11 and 12, this probably occurred very early. Both of these showed large single abscesses, with fetid and copious expectoration.

The history of these cases has been either postpneumonic or postoperative. Two cases followed a tonsillectomy. One case followed an operation on the gallbladder. In none of this series was a foreign body demonstrated as the cause.

The outstanding symptom in these cases was a persistent cough with profuse sputum with a fetid odor, accompanied by a loss of weight. The sputum in two cases did not have the fetid odor. Two cases had

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\* Read before the American Association for Thoracic Surgery, Washington D C April 29, 1922

1 Green N W Lung Abscess Ann Surg 70 539 (Nov ) 1919

2 Lilienthal Howard Resection of the Lung for Suppurative Infections Ann Surg 75 257 (March) 1922

3 Aschner P W The Pathology of Lung Suppuration, Ann Surg 75 321 (March) 1922



been of approximately two years' duration and one had lasted but twenty-one days. The last patient was not operated on and died, overcome by the general infection.

Eight cases, on examination of the sputum, showed no tubercle bacilli, and, in addition, one case gave a negative Pirquet reaction. Two patients did not have the sputum examined while at St. Luke's Hospital, but the sputum had been previously examined for tubercle bacilli by the department of health, New York, with negative results. One patient who died was acutely ill all the time and had no record of examination for tubercle bacilli. In his case there was a massive



Fig 1 (Case 8) —Abscess of the right lung that was regarded as a case of pulmonary tuberculosis for a number of years, the patient being treated at a tuberculosis sanatorium. Roentgen-ray examination revealed the true nature of the condition (Fig 2). Operation by the two-stage method resulted in complete cure (Fig 3).

necrosis of nearly the entire upper lobe. No tuberculosis was present in any of these twelve cases. In three cases, pneumococcus Group IV was found.

Of the patients that were not operated on for lung abscess, one was discharged from the hospital improved, one was cured, and one

died. One came under observation, but was not admitted to the hospital and was cured two months after the onset. Of the patients operated on, five were improved, and three were reported cured.

Four patients had one operation, and four had two operations. Three of the latter were two-stage operations. The first stage consisted in packing down to the pleura, and the second stage in opening



Fig 2 (Case 8) —Circumscribed cavity with fluid level and no evidence of tuberculosis

the abscess cavity. Twice the lung was opened with the cautery. In one case the abscess discharged into the lung after packing with gauze. One patient in whom the abscess had been drained, and who had an overlying empyema, improved and later required a resection of two or three ribs to obliterate the residual empyema cavity.

## DIAGNOSIS

The differential diagnosis lies in the history of the onset, the character of the sputum and the absence of tubercle bacilli (one patient spent six months in a tuberculosis sanatorium, but tubercle bacilli were never found in the sputum) Two other patients had been previously referred to the tuberculosis service of the department of health, city of New

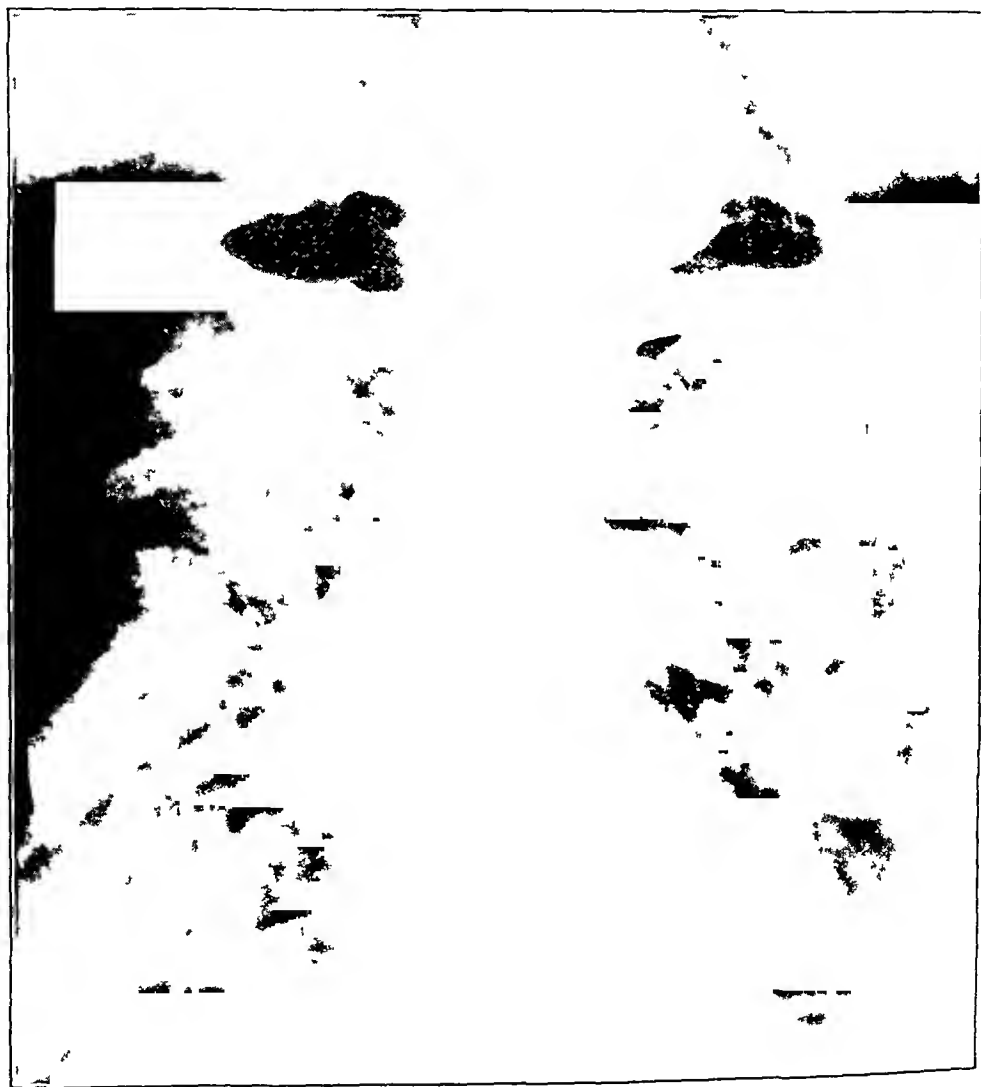


Fig 3 (Case 8) —Disappearance of all evidence of abscess cavity, seven months after operation

York, where, on roentgenographic examination, the diagnosis was corrected Clubbing of the fingers, to a greater or less degree, is one of the frequent physical signs If correctly interpreted, the roentgenographic examination is the most reliable means at our disposal in differentiating the pathologic condition of the lung

## REPORT OF CASES

CASE 1—W, woman (patient of Dr Martin), was admitted, Oct 30, 1916 No tubercle bacilli were found in the sputum A one-stage thoracotomy was performed, Jan 15, 1917 The patient was discharged improved She gave a history of onset of symptoms, four months before the operation, following pneumonia The temperature on admission was 100.2 F, the white blood count, 20,000

CASE 2—L, man (patient of Dr Vogel), was admitted, May 20, 1919 No tubercle bacilli were found in the sputum He was discharged three months after inception of symptoms, without operation, and improved The onset of symptoms occurred eight weeks after pneumonia, with cough, spitting of blood and pain in the right chest The temperature on admission was 100 F, the leukocyte count was 11,000

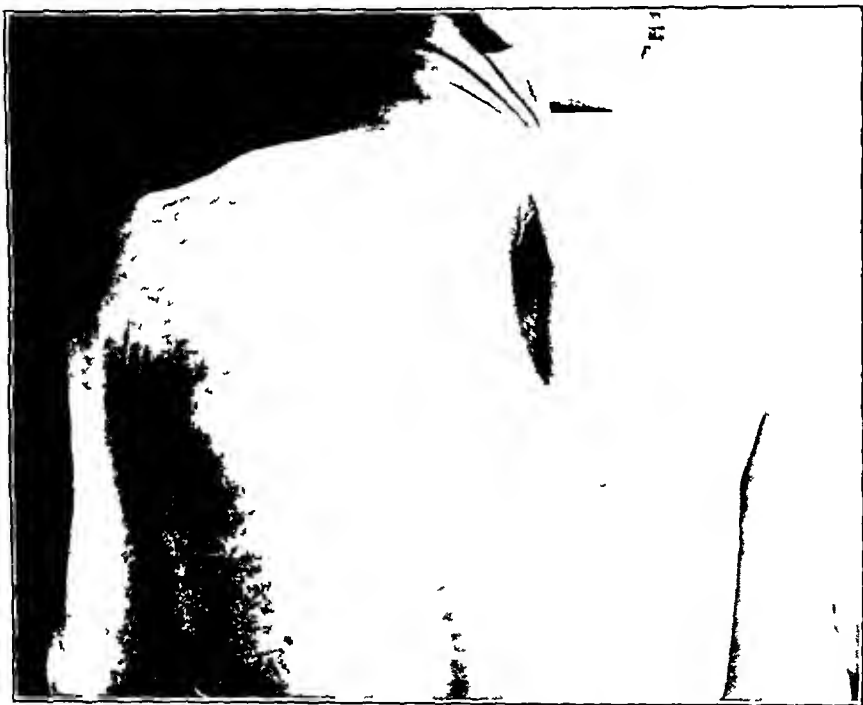


Fig 4 (Case 9) —Abscess of the upper lobe of the right lung, following laparotomy for gallbladder disease, three months previously The patient had presented himself at the clinic of the health department, where a roentgen-ray examination disclosed abscess of the lung (Fig 5) and led to operative treatment and cure (Fig 6)

CASE 3—O'R, woman (patient of Dr Patterson), was admitted, April 22, 1920 No tubercle bacilli and no elastic tissue were found in the sputum Group IV pneumococcus was present This patient was discharged, two years after the inception of symptoms, cured She had been operated on one year and two months previously for empyema following pneumonia One year later, after catching cold and spitting blood tinged sputum, the patient was readmitted The temperature on admission was 104 F The white blood count was 30,000 This case followed pneumonia

CASE 4—C, woman (patient of Dr Mathews), was admitted, April 17, 1920. The onset of symptoms occurred fourteen days after tonsillectomy. No tubercle bacilli were found in the sputum. A one-stage thoracotomy was performed. The patient was discharged four months after the beginning of symptoms, cured. The temperature on admission was 100.4 F.

CASE 5—McI, woman (patient of Dr Green), came under observation, May 11, 1920. She gave a history of onset occurring six days after tonsillectomy.



Fig 5 (Case 9)—Cavity formation with a definite fluid level in the right upper lobe, no evidence of tuberculosis, patient tilted to right side.

A roentgenogram by Dr Wessler revealed a lung abscess, 1 inch (2.5 cm) in diameter, in the right upper lobe, and another roentgenogram, taken two months later, after the patient had first come under observation, was interpreted by Dr LeWald as revealing the abscess cured, with some thickening. The patient was discharged, cured.

CASE 6—S, man (patient of Dr Green), was admitted, Dec 2, 1920, presenting Group IV pneumococcus. Inoculations of a guinea-pig produced no reaction. One operation, consisting of drainage of the empyema cavity and lung abscess, was performed, and later another operation, consisting of resection of two or three ribs to close the empyema cavity, was performed. The patient was discharged, one year and six months after the onset, improved. This case followed influenza. The temperature on admission was 103.6 F. The leukocytes numbered 63,000.

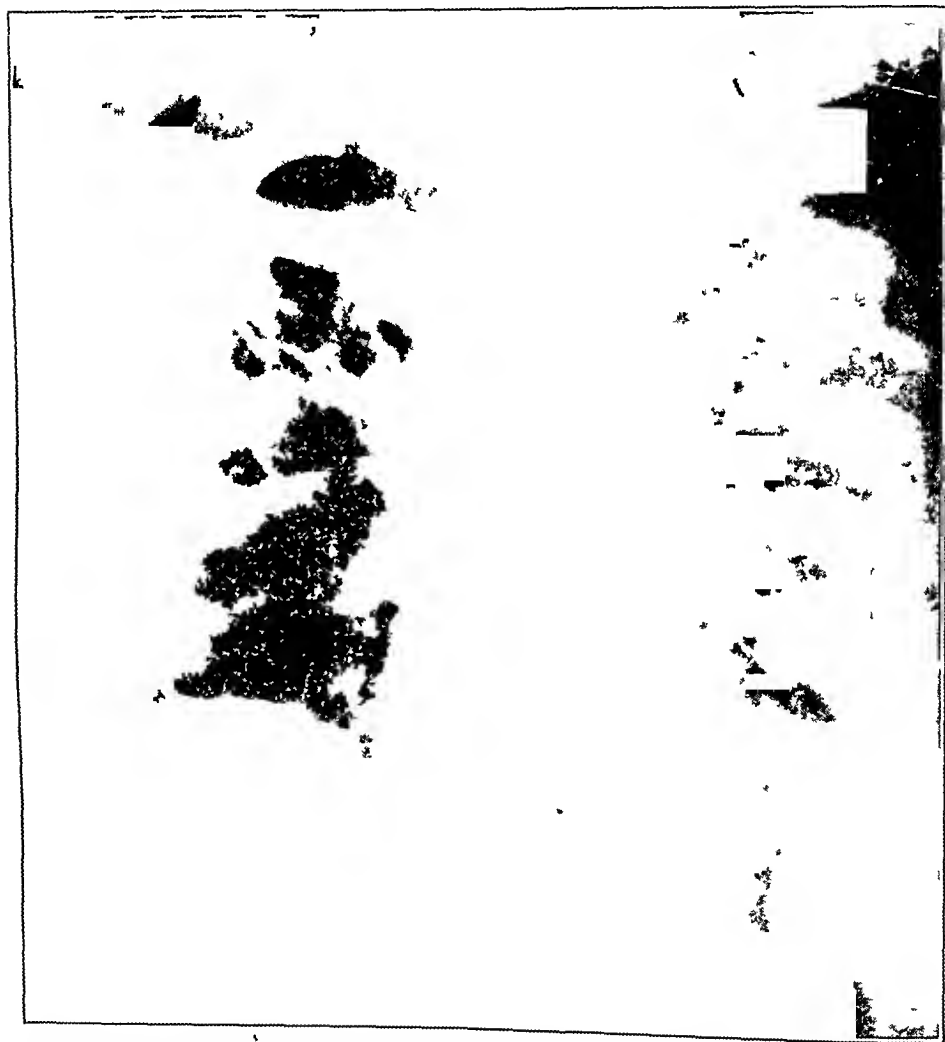


Fig 6 (Case 9) —The cavity had entirely healed, three months after operation.

CASE 7—C, woman (patient of Dr Mathews), was admitted, Oct 31, 1921. Examination was negative for tubercle bacilli, but positive for Group IV pneumococcus. A one-stage operation with drainage was performed seven weeks after a radical breast operation on the right side. The patient was discharged, two months after thoracotomy, improved. Feb 9, 1922, the patient was cured. This case followed pneumonia. The temperature on admission was 100.6 F. The leukocytes numbered 17,800.

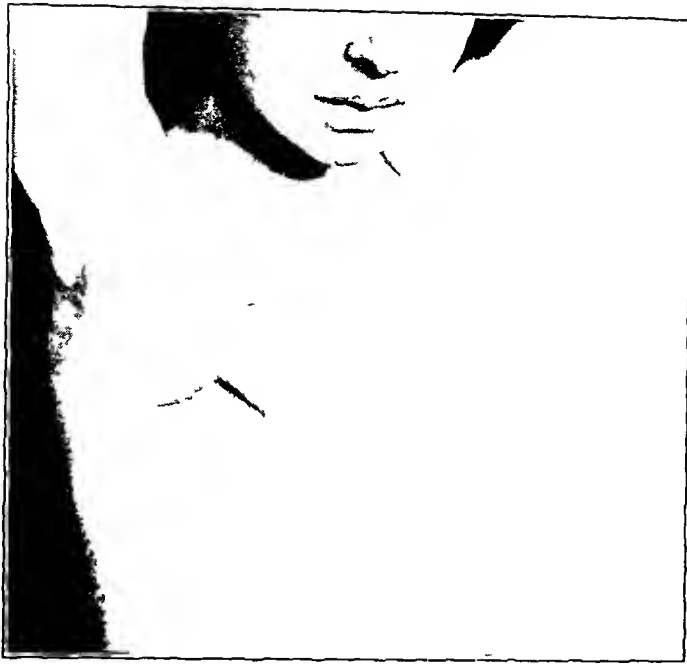


Fig 7 (Case 10) —Abscess of right lung, of two years' duration, the origin of which is unknown At the clinic of the health department, roentgen-ray examination disclosed abscess of the lung (Fig 8), leading to operation and cure (Fig 9)

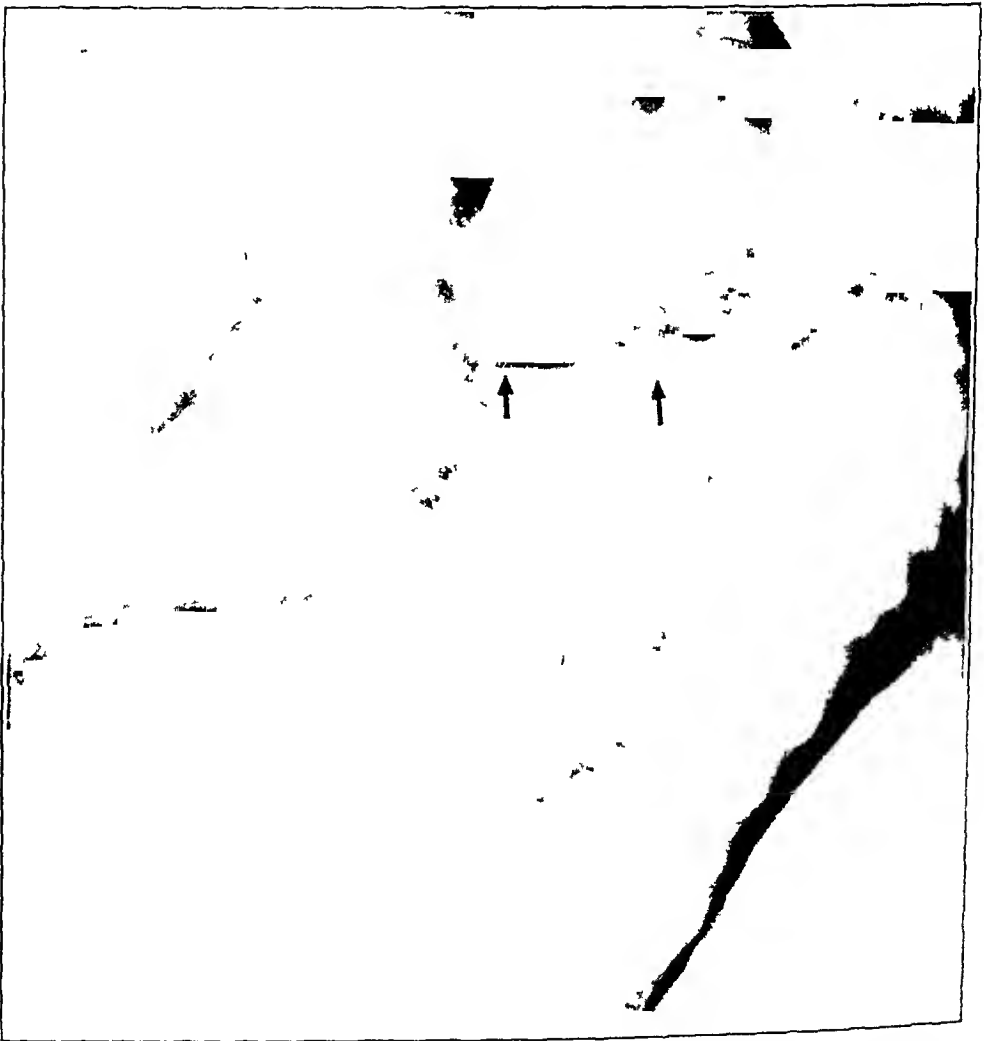


Fig 8 (Case 10) —Abscess of upper lobe of right lung, showing enormous size of cavity, and fluid level, patient tilted to left side

CASE 8—F, man (patient of Dr Green), was admitted in December, 1921. There was no known cause for the abscess. The patient had coughed blood previously. The sputum was negative for tubercle bacilli. A two-stage operation was performed for drainage. In the second operation, the lung was opened by the cautery. The patient had acute symptoms, nine months before admission. Seventeen years previously, however, he was in a tuber-



Fig 9 (Case 10) —Complete drainage of cavity, two months after operation

culosis sanatorium, but tubercle bacilli were never found in the sputum. This patient had gained about 30 pounds (13.6 kg) in weight, and considers himself cured (Figs 1, 2 and 3).

CASE 9—L, man (patient of Dr Green), was admitted, Jan 1, 1922, with a history of symptoms lasting for three months before admission and following a laparotomy for gallbladder disease. The sputum was negative for tubercle



bacilli when examined by the department of health, New York. Operation was performed in two stages for drainage. The lung was opened with the cautery. The patient has gained about 25 pounds (11.3 kg), and is cured (Figs 4, 5 and 6).

CASE 10—D, man (patient of Dr. Green), was admitted in January, 1922. The Pirquet reaction was negative. The sputum was negative for tubercle bacilli when examined by the department of health, New York. Symptoms were severe cough, which had lasted for two years previous to admission.

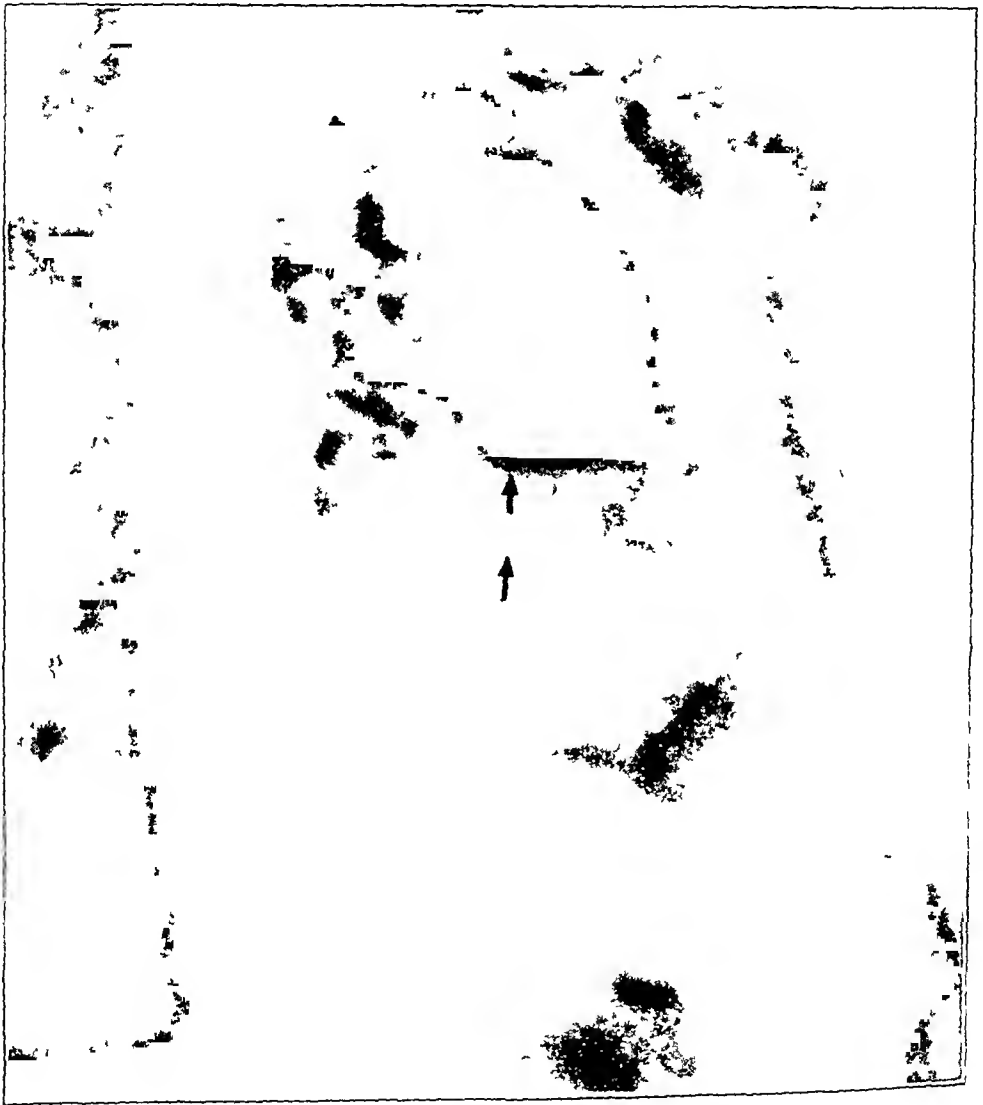


Fig. 10 (Case 11)—Abscess of lung following pneumonia, showing enormous cavity involving the left upper lobe, with two distinct fluid levels, owing to the difference in density of the material in the cavity. This closely resembles the test usually made of the sputum when it separates into two or three layers in a glass.

Operation was performed in one stage for drainage. The patient was improved. The origin of the condition was not determined. The temperature on admission was 99.4 F (Figs 7, 8 and 9).

CASE 11—D M (patient of Dr Martin), was admitted, March 20, 1922. He was acutely ill all the time. There was massive necrosis of almost the entire upper lobe. No examination of sputum for tubercle bacilli was made. He died three weeks after inception of the trouble, which began as pneumonia (Fig 10).

CASE 12—N, woman (patient of Dr Green), referred by Dr Bastedo, was admitted in April, 1922, three weeks after a tonsillectomy. A two-stage operation was performed for drainage, and the abscess was opened by packing gauze into the lung on the abscess. Examination of sputum was negative for tubercle bacilli. The operation was performed three weeks after the onset, and the patient is still improving and is still in the hospital ward, improved.

Our thanks are due to Dr Patterson, Dr Mathews, Dr Bastedo and Dr Martin for allowing us to include their cases among these in this paper, and to Dr D E Ehrlich for referring three valuable cases to us.

# LUNG ABSCESS †

A L LOCKWOOD, M D

TORONTO, ONT

I shall include under the heading abscess of the lung all types and degrees of abscess, except those due to tuberculosis and bronchiectasis, and all degrees of gangrene of the lung except a massive gangrene involving an entire lobe or lung. Because localized gangrenous abscess is so difficult to differentiate from a pure pyogenic abscess, symptomatically, and even at necropsy, and because it is usually impossible to determine whether one has supervened on the other or preceded it, I shall consider the so-called gangrenous abscess as a type of lung abscess per se rather than as a distinct entity.

There are few conditions which, arising often from such trivial and preventable causes as does abscess of the lung, so quickly and completely incapacitate a person, rendering him a burden to himself, his friends and to society. The progressive weakness, the distressing cough, the long convalescence and, above all, the foul smelling and tasting sputum, break the morale of the stoutest patient and present one of the most difficult conditions to treat.

## HISTORY

The history of lung abscess should be read at length by those interested in its treatment. Hippocrates<sup>1</sup> recognized the condition and pointed out that at times the abscess burst into a bronchus and was spat up, and that occasionally it ruptured into the pleural cavity, necessitating drainage.

Since his time, medical literature has abounded in recorded cases of lung abscess. Drainage by cautery puncture, intercostal stab and thoracotomy has been employed since the earliest times. Antiseptic injections and irrigation through the bronchial tree have been practiced. There have been alternate periods of active surgical treatment and of a return to more palliative measures.

A decided advance was made in 1885 when Gluck, Schmidt Block and Biondi<sup>2</sup> showed, for the first time, that partial resection of the

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\* Read before the American Association for Thoracic Surgery, Washington, D C, April 29, 1922

1 Hippocrates, quoted by Koch. *Historisches über die chirurgische Behandlung der Lungencavernen*, Berl klin Wchnschr **11** 194-196, 1874

2 Gluck, Schmidt Block and Biondi. *Die Entwicklung der Lungenchirurgie*, Arch f klin Chir **83** 581-601, 1907

lungs was possible in animals. In 1894, for the first time, pneumothorax was employed for the treatment of a tuberculous abscess, by Forlanini.<sup>3</sup>

Tuffier, Garre and Quincke did a great deal toward stimulating the more logical study of the condition. McKewan's total extirpation of a lung, under chloroform anesthesia, should have marked an epoch in thoracic surgery, but, unfortunately, it seems to have been overlooked by the profession at large. Murphy,<sup>4</sup> in his address on thoracic surgery, in Denver, in 1898, was twenty years ahead of his time. Sauerbruch, Meyer, Lilienthal, Robinson and many others have made most valuable contributions to the subject.

#### ETIOLOGY

The predisposing and direct causes of this condition are well recognized by all members of this society. Particularly, I would emphasize the incidence of lung abscess following operation in the region of the nose and throat when a general anesthetic has been employed. In these days when tonsillectomy is so lightly advised and so frequently employed, it should be pointed out to the profession that lung abscess is not a rare sequel, nor one lightly to be entertained. It should be appreciated that it has occurred almost entirely in patients operated on under general anesthesia. Richardson,<sup>5</sup> in 1912, first pointed out this phenomenon. Bassin,<sup>6</sup> in 1913, collected the reports of sixteen cases following tonsillectomy under general anesthesia. Manges<sup>7</sup> saw nine cases in one year at Mount Sinai Hospital. Wessler<sup>8</sup> states that 28 per cent of the cases of lung abscess seen in the roentgenographic department of Mount Sinai Hospital were due to tonsillectomy. Pottenger<sup>9</sup> reported having seen, in eighteen months, twenty cases following tonsillectomy. Of thirty-two lung abscesses reported by Whittemore,<sup>10</sup>

3 Forlanini, C. Ein Fall von seit sechs Jahren bestehendem durch kunstlichen Pneumothorax behandeltem Lungenabszess, *Munchen med Wchnschr* **47** 124-129, 1910.

4 Murphy, J. B. Surgery of the Lung, *J. A. M. A.* **31** 208 (July 30) 1898, *ibid* 281 (Aug 6) 1898, *ibid* 341 (Aug 13) 1898.

5 Richardson, C. W. Complications of the Operation for Removal of Tonsils, *Laryngoscope* **23** 667-678, 1913.

6 Bassin, C. G. Les complications broncho-pulmonaires consecutives a l'adenoidectomie et a l'amygdalectomie, Paris, Muller, 1913.

7 Manges, M. The Occurrence of Abscess of the Lung After Tonsillectomy, with a Report of Nine Cases in Adults, *Am. J. Surg.* **30** 78-83 (March) 1916.

8 Wessler, H. Suppuration and Gangrene of the Lung. A Study of One Hundred Cases, *J. A. M. A.* **73** 1918 (Dec 27) 1919.

9 Pottenger, F. M. Points of Differential Diagnostic Value in Pulmonary Abscess, Bronchiectasis and Pulmonary Tuberculosis, with an Explanation of the Cause of the Difference in Auscultatory Findings, *Am. J. Med. Sc.* **158** 502-510 (Oct) 1919.

10 Whittemore, W. Lung Abscess, *Surg. Clinics N. Am.* **1** 765-784 (June) 1921.

in 1921, seventeen followed tonsillectomy. Of fifty-four cases that came to the Mayo Clinic, sixteen were due to tonsillectomy. Of 208 collected cases of lung abscess following tonsillectomy, we find only seven in which operation was performed under local anesthesia. Twenty-five thousand tonsillectomies have been performed at the Mayo Clinic under local anesthesia, and only one lung abscess has occurred. That was a terminal process in a pyemia and should not be considered as a true post-tonsillectomy lung abscess. Surely this is irrefutable evidence that the abolition or slowing of the pharyngeal reflex under general anesthesia, by allowing inhalation of infected debris, is the important factor in the etiology. A fractional percentage of the lung abscesses following tonsillectomy are embolic in origin, but the great majority are due to aspiration of the caseous, bacteria-laden content of the tonsils.

Contrary to textbook dictums, lung abscess is a rare sequel of lobar pneumonia. It is probably more common following bronchopneumonia. Aspiration of foreign bodies accounts for a certain percentage of abscesses. A few follow traumatism. Emboli from a distant focus, such as an infected middle ear or a thrombosed lateral sinus, is a definite cause. A few develop from pulmonary embolus.

Time will not permit me to go into the morbid anatomy, pathology and bacteriology of the disease further than to point out a working classification into large and small, single and multiple, acute and chronic, simple acute and acute gangrenous and simple chronic and chronic putrid types. It might also be pointed out that no analogy can be drawn between abscess in the lungs and in any other part of the body.

#### LOCATION OF ABSCESES

It is important to realize that lung abscess occurs about two and one-half times as often on the right as on the left side, and about twice as often in the lower lobes as in the upper. The exact location varies, however, with the etiology. About 80 per cent are peripherally situated and about one-fourth are multiple, but in most cases confined to the same portion of lung.

#### SYMPTOMS

The symptoms vary with the etiology, the general resistance of the patient, the duration of the disease and the extent of pulmonary involvement.

When cough, dyspnea, pain in the chest and the raising of foul sputum are added to the disease or are prolonged after the period that the ordinary affection of the lung or respiratory tract usually persists, abscess should be suspected. Following tonsillectomy and other opera-

tions about the nose and throat, foul expectoration is usually produced between the tenth and fifteenth days

Regardless of the cause, loss of appetite, progressive loss of weight, emaciation, general weakness, pallor, productive cough, foul sputum, pain in the chest, variable dyspnea, fluctuating temperature and leukocytosis characterize the disease. Clubbing of the fingers and watch crystal nails occur. The hemoglobin is reduced in chronic cases. In most cases, the red count is low. Rigors occur at some stage. Fifty per cent of patients have blood in the sputum at some time during the course of the disease. In our cases, it was rare to find elastic tissue in the sputum, though it is usually considered the *sine qua non* of the disease.

The atypical and recurrent types of the disease must be borne in mind.

#### LOCATION OF ABSCESS

Location	Patients	Per Cent
Right side	381 of 537	71
Left side	156 of 537	29
Upper lobes	157 of 447	35
Lower lobes	266 of 447	60
Middle lobe	24 of 447	5
Right upper lobe	40 of 193	21
Middle lobe	24 of 193	12
Lower lobe	67 of 193	35
Left upper lobe	13 of 193	7
Left lower lobe	49 of 193	25
Acute	95 of 221	43
Chronic	126 of 221	57
Peripheral	56 of 71	79

#### DIAGNOSIS

It is a disease of symptoms rather than physical signs. The diagnosis depends on the history, the roentgen-ray findings, examination of the sputum and the general physical examination. On an accurate history, only the majority of lung abscesses can be diagnosed. The affection is three times as common in males as in females. It may occur at any age, but occurs usually between the ages of 25 and 40 years. While a careful physical examination is necessary, thorough fluoroscopic examination and stereoscopic roentgenograms are essential. Roentgenographic examination serves to differentiate tuberculosis, bronchiectasis, empyema, cysts, gangrene, malignancy, aneurysm, etc.

Needling of a pulmonary abscess as a diagnostic method is mentioned only to be condemned.

The bronchoscope should be used, especially if there is any question of the patient's having aspirated something, and, in any case if the abscess is not draining freely through a bronchus.

## COMPLICATIONS

The complications may be many and may be more serious than the disease. Cerebral embolus and pulmonary hemorrhage are especially serious.

## PROGNOSIS

The prognosis must be guarded, depending on the cause, the extent of lung involvement, the complications, the patient's general resistance and the treatment adopted. Abscesses following tonsillectomy offer a more favorable prognosis than those following aspiration of foreign bodies, such as pieces of metal, kernels of corn, and so forth. Metallic bodies have some inherent property of producing gangrenous abscesses. Abscesses due to bronchopneumonia are so often multiple that the prognosis is unfavorable. Embolic types are usually serious. Apical abscesses are more favorable than those located in the middle or lower lobes.

## TREATMENT

Every patient should be given a thorough trial on medical regimen, with postural drainage, before other methods of treatment are adopted. One should persevere with patients until some position is found in which free bronchial drainage is established. Once this position is found, the necessity of frequently assuming this position in order to keep the cavity empty should be carefully explained to the patient.

Inhalations should be employed, not so much for their curative effect per se as to offset the odor, thereby improving the patient's mental outlook and his desire for food. The careful use of the bronchoscope to dilate the main bronchus leading from the abscess, thereby facilitating postural drainage, might be advisable.

If, after a fair trial of this method, the temperature is still elevated and the patient is not eating better, is not coughing less or producing less sputum and is not gaining generally, other measures should be considered.

Artificial pneumothorax should be tried for the small encapsulated abscess not connected with a bronchus, and perhaps for the ordinary long-standing, well localized abscess.

The indications for operation are

1. Operation should be undertaken for all patients who, after a thorough trial of medical treatment are no longer improving or holding their own.

2. Early operation is advisable in all cases of fair sized patent cavities surrounded by markedly fibrosed or calcareous walls.

3. If pneumothorax fails to effect a cure in the small encapsulated abscess not connected with a bronchus, operation should be undertaken early.

4 After thorough medical treatment to put the patient in the best possible condition for operation, surgery should be resorted to in all patients in whom an abscess surrounds a foreign body embedded in the parenchyma, or in whom a foreign body lodged in a bronchus cannot be removed through a bronchoscope

5 Operation is advisable in patients with a very large cavity, producing large amounts of fluid, in whom the danger of drowning themselves in their own sputum is to be feared

*Surgical Treatment*—Resection and direct drainage should be employed in patients who are very dangerously ill. In patients who will stand it, a thoracotomy should be performed. The abscess or abscesses should be localized by thorough palpation. It, or they, should be marsupialized, and at the earliest possible moment closed over with skin flaps from the chest wall. Bearing in mind the relative position of the lobes, the incision should be planned in such a way as to allow direct and easiest access to the area involved.

Resection en masse of a small, completely encapsulated abscess and of a portion of the lung with a foreign body implanted in it is the method of choice.

The danger of postoperative hemorrhage, empyema and cerebral emboli should be avoided.

#### MORTALITY

In adults, the mortality rate in recorded cases has averaged 58 per cent after medical treatment and 35 per cent in those treated surgically. In children, it has been much higher.

Of fifty-four patients whose cases I have recently reported, twenty-seven were treated surgically and twenty-seven medically. Forty-nine were chronic cases. The average duration of symptoms was nineteen weeks before examination. Twenty-five were of the type classed as gangrenous abscess. In sixteen, the complications were almost as serious as the disease itself. Of the twenty-seven patients treated medically, sixteen were cured, three improved, five not improved and three are dead. Of the twenty-seven patients treated surgically, thirteen are cured, three improved with fistulas, and eleven are dead. Analysis of the eleven deaths reveals the extent of the disease before coming for treatment, and the impossibility of averting death in a certain percentage of long neglected cases.

The greatest danger in medical treatment is that the time is not recognized when medical treatment should give way to surgical.

#### CONCLUSIONS

1 Contrary to the opinion of the early writers that abscess of the lung is a common sequel to lobar pneumonia a survey of the reported



cases of the last century would lead one to conclude that it is a rare sequel

2 By lowering the resistance in the lung tissue itself, lobar pneumonia, bronchopneumonia and influenzal pneumonia predispose the patient to the development of lung abscess following pyogenic infection

3 Lung abscess occurs more often between the ages of 25 and 40. It is three times as common in males as in females, it occurs two and one-half times as often on the right side as on the left, and about twice as often in the lower lobe as in the upper. Three out of four cases are peripheral and involve the pleura, and one out of four is multiple.

4 It must be borne in mind that, recently, a high percentage of lung abscesses have been the result of neglect or mismanagement on the part of the nose and throat surgeons, the oral surgeons and the dentists. Such neglect or mismanagement is manifested in the selection of the anesthetic, in not keeping the patient's head low and in not taking sufficient precautions to prevent the patient from inhaling foreign matter. Such a sequel may be avoided by (1) employing a local anesthetic whenever possible in surgery of the mouth, nose and throat, and in teeth extraction, (2) keeping the head low during such operations if a general anesthetic is employed, until the patient has thoroughly aroused from it, (3) taking care to prevent blood and mucus from accumulating in the throat and being aspirated, and (4) better hemostasis in such work.

5 The diagnosis depends on the history, the amount and nature of the sputum, the roentgen-ray and physical examinations.

6 A study of results in these cases has led me to conclude that surgery should not be employed so soon as the diagnosis has been made, except as indicated. The mortality has been unnecessarily high in many instances. Instead, thorough medical treatment, with postural rest and drainage, should be instituted. When this fails, pneumothorax should be produced in selected cases, and surgery reserved for those patients who do not respond to the other two methods.

7 The exploratory needle should not be employed.

8 When surgery is decided on, paravertebral and local anesthesia, if necessary with gas and oxygen, should be used, and in the majority of patients a more deliberate, extensive and logical operation should be planned than resection of the chest wall over the abscess, and cautery or blunt puncture of the abscess.

9 If the patient's condition is such that extensive operation would involve too much risk, resection, blunt puncture and exploration of the abscess with the finger should be the limit of surgery.

10 The surgeon, physician and roentgenologist should be intimately associated in making the diagnosis and in the care of these patients.

# THE SURGICAL TREATMENT OF BRONCHIECTASIS

WITH A REPORT OF THREE CASES OF REMOVAL OF  
A LOBE OF THE LUNG \*

EVARTS A GRAHAM, M D

ST LOUIS

Existing methods of treating bronchiectasis are far from satisfactory. In general, the radical methods are associated with a high mortality, and the less radical ones accomplish little. Improvements will come probably through accumulated experience. With the view of adding to the total of recorded experience, three cases are here presented. Various measures which have been used are (1) pneumotomy, with an attempt to drain a cavity, (2) thoracoplasty, (3) ligation of branches of the pulmonary artery, a method suggested by Sauerbruch<sup>1</sup> to produce shrinkage of the affected portion of the lung, (4) artificial pneumothorax, (5) partial pneumectomy. It is evident that three general principles underlie all of the methods of treatment enumerated above. These are drainage, compression or shrinkage, and excision. Some cases which are associated with a foreign body in the lung will show great improvement after its removal, especially if it is lodged in one of the larger bronchi and if it can be removed through a bronchoscope. Here again, however, we are dealing with a method which probably owes its success largely to drainage.

In any advanced case of bronchiectasis, the bronchioles and some of the larger bronchi are not only enormously enlarged, but their walls are also greatly thickened by fibrosis, as a result of long-standing inflammation. It would seem unlikely, therefore, that much could be expected either from the establishment of open drainage or from any procedure which was aimed at compression of the affected portion of the lung. Open drainage in such cases, with the creation of a bronchial fistula, will frequently diminish the amount of sputum and will give some relief, but I have never seen a patient made well by such a method. In fact, it would seem difficult to understand how complete healing could occur. It is probable that cases of patients reported as made well by such a method have really been lung abscess rather than bronchiectasis. Methods based on the principle of compression or

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\* From the Department of Surgery, Washington University School of Medicine

\* Read before the American Association for Thoracic Surgery, Washington, D C, April 29 1922

<sup>1</sup> Sauerbruch. Die Bronchiectasen. Cong de la Soc Internat de chir. Rap 1911, p 269

shrinkage of the lung cannot be expected to accomplish much in advanced cases because of the extreme fibrosis of the affected bronchi. In fairly early cases, however, compression with artificial pneumothorax will sometimes yield excellent results. Dr J J Singer and I now have under observation a patient who has gained more than 50 pounds (227 kg) in weight and who has been free from all symptoms for more than a year as a result of using artificial pneumothorax at intervals. This case may be one of bronchiectatic abscess of the type so designated by Lilienthal<sup>2</sup> and by Aschner<sup>3</sup>. Sauerbruch's method of ligation of branches of the pulmonary artery obtained results which were certainly not strikingly successful. The method does not seem to be a good one. In another case, Dr Singer and I saw a temporary beneficial effect following an exploratory operation and a partial thoracoplasty consisting of the extensive removal of three ribs over the affected lobe.

If the case is one in which there is a more or less general dilatation of the bronchi and bronchioles in a lobe, probably the only procedure which, on rational grounds, can be expected to give complete relief is extirpation of the diseased portion. This implies usually the extirpation of at least one lobe, for the reasons that most often the whole lobe is affected, and also that it is generally easier technically to remove the whole lobe than it would be to attempt to find only the portion which might be involved. Unfortunately, however, lobectomy has been associated with a high mortality, and the results have not always been satisfactory even when the patient has survived the operation. Less radical measures than lobectomy, however, have also been unsatisfactory and have likewise been associated with high mortalities. Summaries of results from the literature are likely to be confusing because, probably in many cases, there has been no sharp differentiation between a case of lung abscess which was communicating with a bronchus and a case of bronchiectasis. This must have been so particularly before the use of the roentgen ray.

Quincke<sup>1</sup> summarized fifteen cases treated almost entirely by incision into the lung. Of these patients, one was entirely healed, six (40 per cent) were improved, two (13 per cent) remained unhealed, and six (40 per cent) died as a direct result of the operation. Thus, 53 per cent were either unhealed or died. Tuffier's<sup>4</sup> compilation of results is given in Table 1.

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2 Lilienthal Howard. Resection of the Lung for Suppurative Infections, with a Report Based on Thirty-One Operative Cases in Which Resection was Done or Intended, *Ann Surg* 75:257 (March) 1922.

3 Aschner P W. A Pathological Study of the Material, *Ann Surg* 75:318 (March) 1922.

4 Quoted by Sauerbruch Footnote 1.

Sauerbruch,<sup>1</sup> in 1911, found that of 123 patients with bronchiectasis who were treated by pneumotomy, forty (33 per cent) were said to have been healed, seven (6 per cent) were improved, thirty-three (27 per cent) were unhealed, and forty-three (35 per cent) died

Heidenham<sup>5</sup> seems to have been the first to undertake deliberately the removal of a lobe of the lung for bronchiectasis. He successfully removed the left lower lobe after two previous operations had been performed for drainage. A permanent bronchial fistula remained, however. In 1914, Willy Meyer<sup>6</sup> found that sixteen cases had been reported in which pneumectomy had been performed for bronchiectasis. Of this number, eight patients were classed as cured or improved, and eight died. In 1915, he reported the case of another patient on whom he operated successfully. Robinson,<sup>7</sup> in 1917, reported seven cases with three deaths. It is uncertain, however, how many of these cases were entirely successful from the standpoint of freedom from symptoms, complete healing, etc. Lihenthal<sup>2</sup> has recently contributed a summary of his very remarkable experience. This work constitutes the largest

COMPILATION OF RESULTS OBTAINED BY TUFFIER

Operation	Cases	Improved or Healed	Died	Mortality, Per Cent
Pneumotomy	38	28	10	26.3
Pneumectomy	1	0	1	100
Thoracoplasty	1	0	1	100
Puncture (trocar)	5	3	2	40

single experience with lobectomy in bronchiectasis which has been reported by any surgeon. Although his article deals with thirty-one cases of suppurative infections of the lung in which resection was either performed or intended, it deals actually with twenty-one cases diagnosed as bronchiectasis in which a resection of a portion of the lung was performed. Of this number, seven patients (33 per cent) were reported as well, twelve (57 per cent) died, and, of the remaining two patients, one was reported as convalescent and the other as still having cough and expectoration. Also, one of the patients classified as well still had a small fistula.

5 Heidenham. *Augedehnte Lungenresektion wegen Zahlreicher eiternder Bronchiektasen in einen Unterlappen*, *Verhandl. d. deutsch. Gesellsch. f. Chir.* 30: 636, 1901.

6 Meyer, Willy. *On Bronchiectasis*, *Tr. Am. Surg. A.* 32: 592, 1914.

7 Robinson, Samuel. *The Surgery of Bronchiectasis, Including a Report of Five Complete Resections of the Lower Lobe of the Lung, with One Death*, *Surg. Gynec. & Obst.* 24: 194 (Feb.) 1917, *The Resection of the Lobes of the Lung*, *Discussion*, *J. A. M. A.* 69: 355 (Aug. 4) 1917.

Including the three cases of my own reported here, it becomes evident that the literature contains reports of forty-eight cases of bronchiectasis in which resection has been performed. Of this number twenty-five patients have died, presumably as a result of the operation, a total operative mortality, therefore, of 52 per cent. Probably, however, isolated fatalities have occurred here and there which have not been reported, so that the operative mortality has perhaps been actually higher than 52 per cent. Furthermore, not all of the patients that have survived the operation can be considered well. In 1917, Smith and Mudd<sup>8</sup> carefully analyzed the cases reported up to that time, and they considered that only three could be regarded as complete successes, two of Lihenthal's and one of Robinson's. It would appear now, however, that in six cases of Lihenthal's complete series there have been perfectly satisfactory results and in one of my own. This then would make eight complete successes out of forty-eight cases in which resection has been performed. In other words, in only 17 per cent have complete successes occurred.

The natural query, therefore, is: Should the operation be considered a justifiable one? I believe that it is justifiable in properly selected cases, because the misery of many of those afflicted with the condition is beyond description. In most of the advanced cases, the patients are social outcasts, unable to find employment or to enjoy ordinary human associations. To many of them, death would come as a welcome relief from their misery, and, indeed, some of the patients threaten suicide if they cannot be given relief. In a series of twenty-one cases of bronchiectasis studied by Dr J. J. Singer and myself, no less than six patients have implored us to perform a resection in spite of being fully informed as to its dangers. In three of the cases, we have refused because we felt that the proper indications for the operation were not present. Moreover, almost certainly the operation will become safer with improved technic. Present methods will be supplanted by improvements which will greatly reduce the mortality.

What are the indications? There seems to be a rather general agreement that at present, in the undeveloped state of the technic of resection, the most important indications are: (1) failure of more conservative methods, (2) age, not too advanced, preferably under 35 years, (3) restriction of the process to one lung, and preferably to one lobe, (4) absence of other conditions which would themselves greatly increase the hazard of the operation, (5) performance of the operation by one who is experienced in thoracic surgery, a tyro will almost surely fail.

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<sup>8</sup> Smith, E. and Mudd, H. A Modification in Method of Pneumotomy for Bronchiectasis, *Tr. A. Am. Phys.* 32:313, 1917.

What sort of lobectomy shall be performed? There are, in general, two methods of approach to the lung, one through an intercostal incision, and the other after a preliminary resection of ribs. The former method has been used extensively by Lilienthal in performing a one-stage resection, and the latter was used by Robinson in the performance of a multiple-stage resection. The advantage of the former method is that it leaves less deformity, but its disadvantages are that it does not provide so good an opportunity for a multiple-stage operation and often does not afford so good an exposure as the latter. The details of the technic of each method have been described by Lilienthal<sup>2</sup> and by Robinson,<sup>7</sup> respectively.

The causes of the high mortality from a resection of part of the lung in cases of bronchiectasis are many. They seem to be either immediate or late. Of the immediate causes, the chief seem to have been respiratory failure, cardiac failure, hemorrhage and shock. Respiratory failure is not likely to occur if there are strong adhesions between the unaffected lobe on the side on which operation was performed and the chest wall, or if care is taken not to have too large a free opening. These findings are in accord with former work done by R. D. Bell and myself,<sup>9</sup> in connection with the mechanics of open pneumothorax. Diminishing the size of the opening by the use of gauze compresses or by delivering the lobe outside will usually overcome any respiratory embarrassment which may occur during the operation. After the operation, it is desirable to exclude the free entrance of air by applying a fairly firm pad of dressings over the wound. This procedure will tend to minimize the dyspnea which may occur immediately after the operation. It seems to me that one of the advantages of a multiple-stage operation is that it is possible at one stage to create adhesions between the unaffected lobe and the chest wall before proceeding to the resection of the affected lobe. Robinson showed that, by packing gauze around the affected lobe, adhesions will be produced between the other lobe and the chest wall, which will be sufficiently firm in a week or ten days to permit the resection without breaking up the desired adhesions. I have found, however, that sometimes a longer time is required. In order to be sure, therefore, of firm adhesions, a period of about two weeks should elapse. Respiratory failure during the operation, even in a case without adhesions, may be minimized also by a proper kind of anesthesia. To accomplish this, the anesthetic may be given through a catheter into the pharynx, with a little pressure supplied by a foot

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<sup>9</sup> Graham, E. A. and Bell, R. D. Open Pneumothorax. Its Relation to the Treatment of Empyema, *Am. J. M. Sci.* 56: 839 (Dec.) 1918. Graham, E. A. The Importance of the Vital Capacity in Thoracic Surgery. *J. A. M. A.* 75: 992 (Oct. 9) 1920.

bellows or a mechanical pump, or, if gas is used, a tightly fitting face mask will accomplish a perfectly satisfactory inflation of the lungs. My own choice for intrathoracic work is the latter method.

The sudden cardiac failure which sometimes occurs in these operations is perhaps partly due to manipulation of the heart and sudden changes in its position. Almost invariably after the operation, the pulse rate becomes high, a rate of 150 is not uncommon. To combat this high pulse, Lilienthal has recommended that digitalis be given in sufficient amounts before the operation and over a long enough period of time to obtain a good digitalis effect. Serious hemorrhage is not a common complication, but, nevertheless, it is wise, before the operation, to make all necessary arrangements for a transfusion of blood.

#### COMPLICATIONS

Of the late complications of the operation, infection is most serious. It is this complication which probably is responsible for most of the deaths. Infection seems to be unavoidable. At least, for the sake of safety, in each case, infection should be expected and provision made for drainage. The stump of the lung after the resection always contains virulent bacteria, and there is no method by which it can be sterilized. So far as I am aware, every case has developed a bronchial fistula if death did not occur too soon. This, however, has usually closed spontaneously. Efforts, therefore, should be directed toward minimizing the effects of infection. If only a small portion of the pleural cavity becomes infected, the results will be less serious than if practically the whole pleural cavity is exposed. This fact, to my mind, constitutes another important reason for not performing a resection in the presence of a free pleural cavity. It serves to emphasize the importance of having part of the pleural cavity first obliterated by the creation of adhesions between the unaffected portion of the lung and the chest wall. This constitutes, it seems to me, an argument in favor of an operation based on the principles of the one devised by Robinson. For, by a multiple-stage operation, it is possible to create adhesions at the desired places by temporarily packing in gauze at one stage of the operation. In Case 2, I believe the result might have been different if strong adhesions had existed between the unaffected portion of the lung and the chest wall, so that that portion of the pleural cavity would have been obliterated. The presence of sufficiently strong adhesions to obliterate the portion of the pleural cavity occupied by the unaffected portion of the lung is desirable, both from the standpoint of minimizing respiratory difficulties and of minimizing infection.

The mediastinal space is also likely to be infected in some cases. This may be due in part, to a retraction of the stump of the bronchus if care is not taken to avoid it. In my three cases, I attempted to avoid

it by leaving clamps on the pedicle, the handles of which projected from the wound and firmly anchored the root of the lobe for about four days, until adhesions could form. Lilienthal has left his ligatures long, so that they could be brought out of the wound and anchored. Infection may also spread into the pericardium, and there may also be a severe infection of the remaining portion of lung as well as of the other lung. Here again, it would seem possible to create a leukocytic wall of defense in the pericardium and the mediastinal pleura before exposing these structures to contamination by the contents of the stump of the bronchus. It is to be expected that such a result would occur as an effect of the gauze packing introduced in a stage preliminary to the resection, for the purpose of creating adhesions between the unaffected portion of lung and the chest wall. Another point of importance in connection with the question of infection is the amount of necrotic tissue present. In order to avoid the danger of late hemorrhage from the stump, it is wise to leave a considerable portion of lung tissue (from 0.5 to 1 cm.) beyond the ligatures or the clamps. Unless provision for adequate drainage is made, this necrotic tissue, harboring various anaerobic organisms, will become a serious menace. In view of the more recently developed chemical theories of shock (compare summary by Cannon<sup>10</sup>), necrotic tissue must be regarded as constituting a serious menace to life if its products can be absorbed.

It would seem to be desirable to use early and frequent irrigations with surgical solution of chlorinated soda (Dakin's solution) in order both to inhibit the development of infection and to hasten the separation of the necrotic tissue. There are certain difficulties, however, connected with its systematic use in all cases. For the first day or two, these patients are likely to be extremely uncomfortable, and it seems doubtful how wise it is to subject them to even the slight disturbance associated with the systematic use of irrigations by the Dakin-Carrel method. Later, a bronchial fistula develops, and then it is difficult to avoid flooding the bronchus with the solution.

Progress in the technic of resection of the lung will probably come about largely through development of methods which will minimize the inevitable infection. Any procedure which will permit the easy and safe creation of firm adhesions between the unaffected portion of lung and the chest wall will serve greatly to reduce the mortality of the operation, for the double benefit of a minimum of pleural cavity to be infected and a minimal amount of respiratory disturbance during and immediately after the operation will result.

Records of three cases are presented in which lobectomy has been performed. The essential features of the operative procedure are given

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<sup>10</sup> Cannon, W. B. Studies in Experimental Traumatic Shock. IV. Evidence of a Toxic Factor in Wound Shock. *Arch. Surg.* 41 (Jan.) 1922.



in the respective case reports. In each case, the anesthesia was produced by nitrous oxid and oxygen, through a closely fitting face mask, preceded by a hypodermic injection of morphin,  $\frac{1}{4}$  grain (0.0162 gm), and atropin,  $\frac{1}{100}$  grain (0.00065 gm). After the operation in each case, morphin was given freely to control the pain.

#### REPORT OF CASES

CASE 1—A boy, aged 17, entered Barnes Hospital, Nov 1, 1920, referred to me by Dr J J Singer, who had made a diagnosis of bronchiectasis involving the left lower lobe. For fifteen years, the patient had had a chronic cough. For the last two years, this had been worse and had been accompanied by expectoration of a large amount of offensive sputum. This amounted to nearly a pint of sputum a day. It was usually yellowish green and occasionally

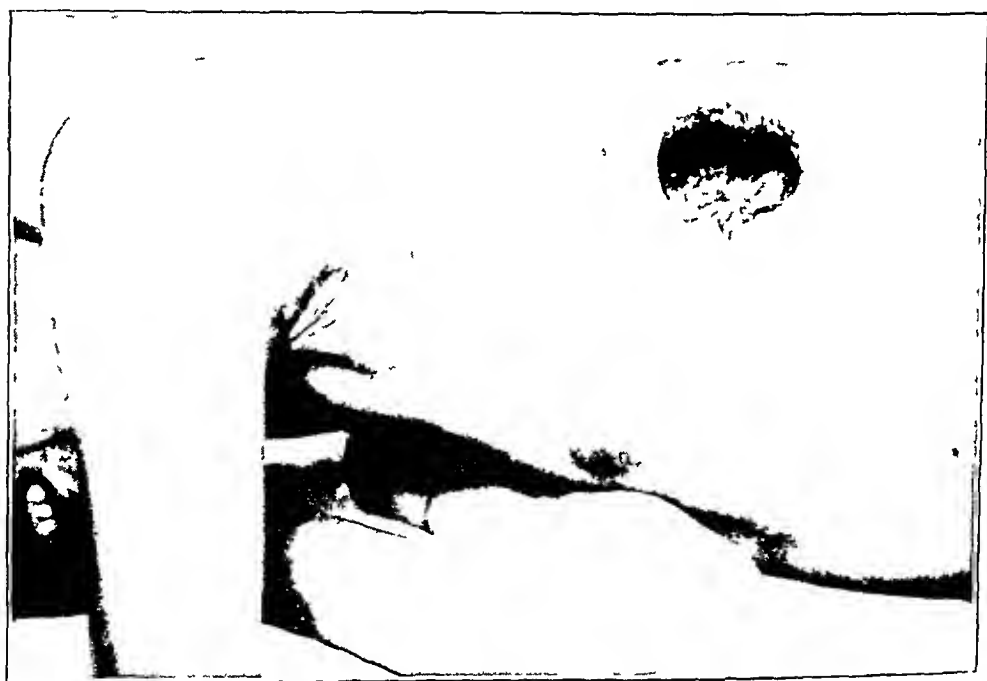


Fig 2 (Case 1)—Patient, six weeks after operation. A bronchial fistula was present at this time.

streaked with blood. There had been no active hemorrhage. There was no pain. The appetite was good. The patient had learned to free himself of sputum by bending over. Coughing started the flow, which continued until the sputum was expelled. He had been treated, about a year previously, in the Jewish Hospital by Dr Sale, who made a pneumothorax on the left side. He received no benefit from this treatment and stated that he felt worse as a result of it, because since then he had had pain in the chest. He had spent several months in Colorado without result. His sputum had been examined repeatedly for tubercle bacilli with negative results. He had had measles at 5 years of age and whooping cough at 6 years. There was no evidence of pneumonia at the time of the onset of the chronic cough beginning at the age of 2.



Fig 1 (Case 1) —Left lower lobe from Case 1 after resection. Almost every bronchiole is enormously thickened and dilated. The cyanotic color of the lobe is characteristic.



*Examination*—The patient was fairly well nourished and somewhat cyanotic. He weighed 131.5 pounds (59.7 kg), and was 5 feet 9¼ inches (177 cm) tall. The shoulders were stooped, the expression was listless. There was marked clubbing of the fingers and toes, prominent mammary glands, offensive breath, slight asymmetry of the chest. The left side of the chest was flattened, with limited expansion. The left clavicle was slightly more prominent than the right. The chest circumference on the left side was 17.25 inches (43.8 cm), right side, 18 inches (45.7 cm), expansion, 1 inch (2.5 cm). Tactile fremitus was decreased on the entire left side. There was dullness over the left lower

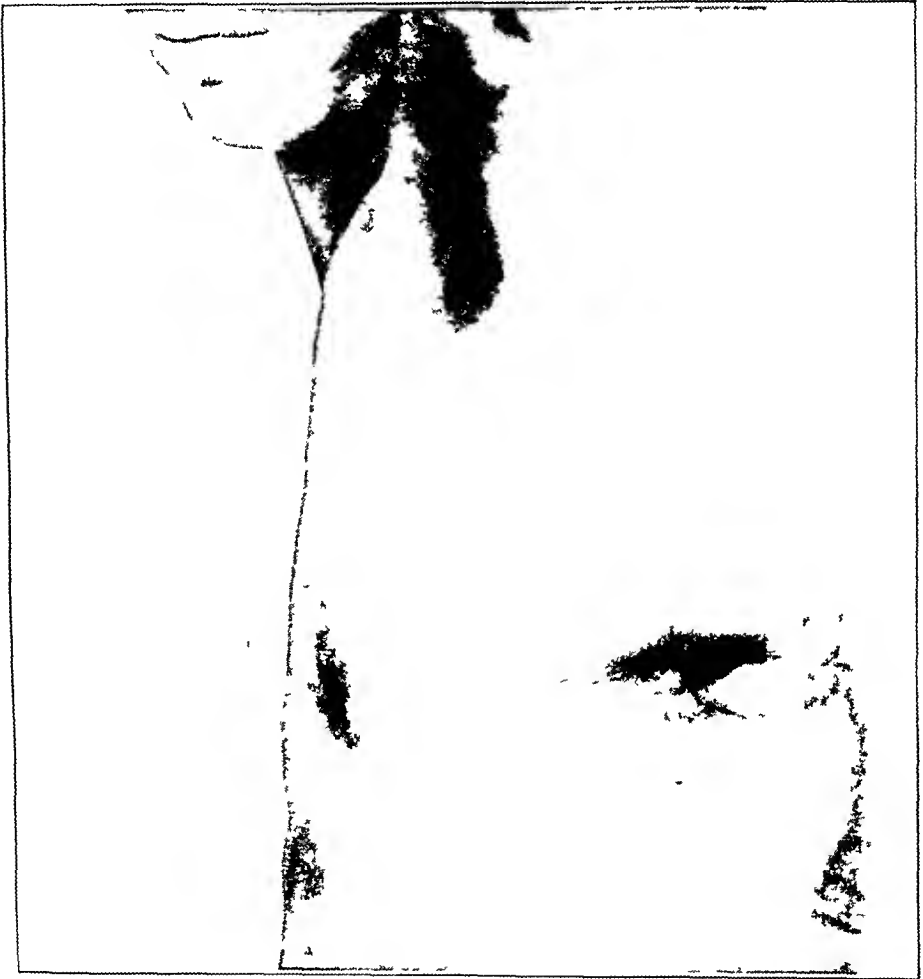


Fig 3—Wound completely healed, three months later

lobe. The heart was displaced somewhat to the left, there were no murmurs, but there was slight sinus arrhythmia. The blood pressure was systolic, 110, and diastolic, 65. The liver was slightly palpable in the epigastrium. The reflexes were all present. The Wassermann reaction was negative. The temperature was 98.2 F, the pulse, 80, respirations, 18, hemoglobin, 90 per cent, red cells, 5,040,000, leukocytes, 9,580. The urine was normal. The electrocardiogram was normal. The roentgen ray revealed an extensive infiltration of the left lung toward the base, with displacement of the heart to the left. There was an area of pneumothorax in the left apex.

*Operation*—November 6, the first-stage operation was performed. About 5 inches (127 cm) of each of the seventh, eighth and ninth ribs was resected on the left side, from the angles to the mammary line. The corresponding intercostal bundles were excised. The pleura was noticeably thickened and was not opened. The first stage terminated after closing the skin with silk-worm and silk sutures, without drainage. There was no marked reaction to the first-stage operation, but elevation of temperature of 1 degree, and a faint trace of albumin in the urine, with a few hyaline and granular casts. Healing occurred by primary intention. November 22, the old flap was turned up, the



Fig 4—One year after the operation. There is no impairment of motion of the arm.

pleura was opened, with but little change in the respiration at first. Adhesions between the upper lobe and the chest wall were so delicate that separation occurred when the finger was introduced into pleural cavity. The pleura was about one-half inch (127 cm) thick. There were extensive adhesions between the diaphragm and lung. The lower lobe was dark, firm and nodular. Adhesions between the lung and diaphragm and chest wall were broken up with the finger. Gauze soaked in petrolatum was packed about the lower lobe. The second stage was terminated. The reaction was more severe after the

second stage than after the first. The temperature on the following day was 101 F, pulse, 110, respiration, 22. There was considerable discharge of bloody serum. On the sixth day after operation, the packing from the chest was removed, under nitrous oxid anesthesia, and three Carrel tubes were inserted for irrigation with Dakin's solution. The temperature continued to be elevated, reaching a height of 104 F, until the ninth day after operation (Dec 1), when it fell to practically normal and remained so until the third stage of the operation. December 14, the patient weighed 117 pounds (53 kg).

The cavity was kept clean after the first two or three days by irrigation with the Dakin solution and, December 31, the third stage of the operation was carried out. With nitrous oxid anesthesia, the old incision was reopened and the lung was found to have retracted upward somewhat. In order to provide more space, about 4 inches (10 cm) of each of the fifth and sixth ribs was removed. The lower lobe was densely adherent all around. Many adhesions had to be cut. The greatest difficulty was in separating the



Fig 5—Anterior and posterior views of patient, showing healed scar and extent of deformity

adhesions between the lung and the diaphragm. The separation between the upper and middle lobes was easy. Curved clamps were placed on the hilum, and the lobe was amputated. The clamps were left in position. The wound was packed with petrolatum gauze and covered with several pads to exclude air. The operation was well tolerated and lasted forty-five minutes. January 3, the clamps were removed from the hilum without bleeding and with no evidence of bronchial fistula. There had been very little reaction to this stage of the operation. The maximum temperature was 102 F, with an average of about 100 F. The average pulse rate was 130, respiration, 25. There was no cough. Dakin irrigations were continued regularly from the time of removal of the clamps. January 8, the patient tasted Dakin's solution for the first time and began to cough during irrigation. January 10, a bronchial fistula was observed. Instead of ordinary Dakin's irrigations, one irrigation a day was substituted, with the patient in the sitting posture, care being taken

to avoid entrance of fluid into the fistula. Recovery was practically uneventful except for an attack of acute tonsillitis. He was discharged from the hospital, February 19, with a bronchial fistula about the size of a lead pencil. This healed entirely spontaneously, about two months later. It has remained healed ever since. There has been practically no cough since the operation, and the patient is now able to work for the first time in about three years. He also indulges in athletics and has become an amateur boxer of considerable ability.

CASE 2—A man, aged 25, had symptoms which had begun five years previously with a severe cough. About six months later, he began raising, every day, about one-half cupful of sputum, which was sometimes dark brown and other times white. The condition had continued until the time of examination, in fact, the symptoms were at that time more distressing than they had ever been. He then raised from 2 to 3 cupfuls of sputum in twenty-four hours. The sputum had a very foul odor. Beginning in 1917, for a period of about

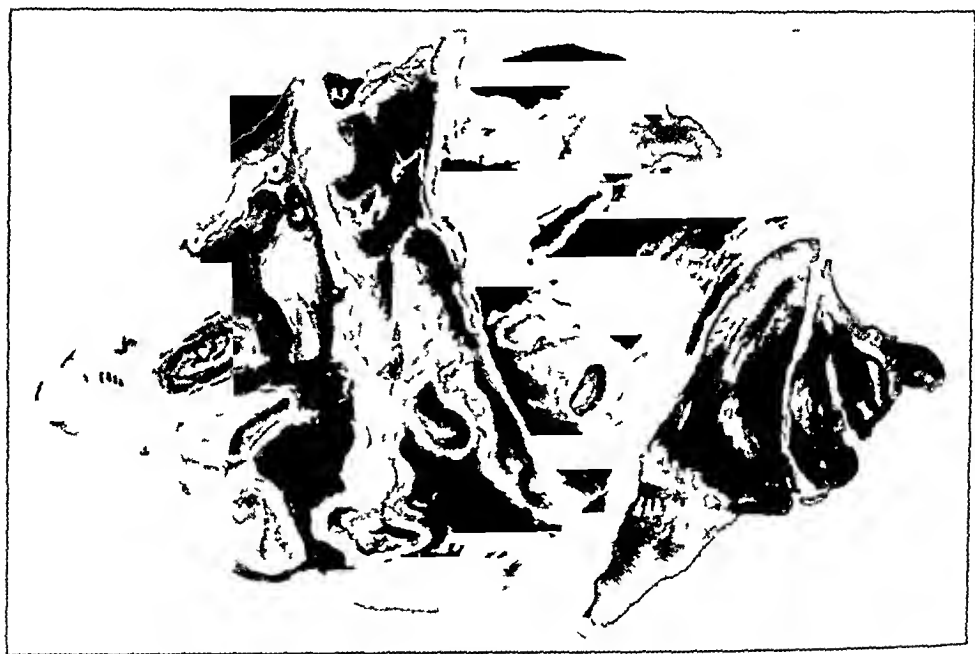


Fig 6 (Case 2)—Resected lobe

three years, he was treated for pulmonary tuberculosis at several sanatoriums in the far west. He had not been able to work much during the last four years. He was from 10 to 15 pounds (4.5 to 6.8 kg) under normal weight. Chills and fever had been frequent, until, during the last year, he discovered how to drain his lungs by gravity. His family history and previous history were of no particular importance.

*Examination*—This indicated involvement of the left lower lobe. There was moderate clubbing of the fingers and toes. The temperature, pulse and respirations were normal. The urine was normal except for a slight trace of albumin on one occasion. There was slight secondary anemia, red cells, 4,000,000, hemoglobin 79 per cent, leukocytes, 10,000. The Wassermann reaction was negative. *Staphylococcus albus* and *Streptococcus viridans* were found in the sputum. The vital capacity measured 5,250 cc, the tidal-air 400 cc.

*Operation*—Sept 9, 1921 a crescentic incision was made, with convexity downward, beginning about 1½ inches (3.8 cm) from the spine at the level of

the fifth rib, passing downward to cross the eighth interspace in the scapular line, coming up again to the fifth rib in the anterior axillary line. The seventh, eighth and ninth ribs reflected subperiosteally from a point slightly posterior to their angles to a point about 1 inch (2.5 cm) anterior to the anterior axillary line. The muscle bundles were then excised. The upper lobe could be seen to move on respiration. The pleura was not opened but was swabbed with tincture of iodine with the idea of establishing adhesions between the upper lobe and the chest wall. The flap was turned down and sutured without drainage. After the operation, pads were placed over the wound and anchored firmly in position by means of long adhesive strips in order to create a buttress as a support for the patient's coughing. Convalescence after this first stage was uneventful. It is interesting to note that, September 22, the vital capacity was only 2,750 cc as compared with 5,200 cc before operation. September 23, the flap of skin and soft parts was turned up, the pleura opened and the lower lobe found to be densely adherent. It was separated from its attachments with great difficulty. The most troublesome adhesions were between the lung and the diaphragm, on the one hand, and the lung and the posterior wall, on the other. The adhesions to the pericardium caused little trouble. The interlobar fissure was completely obliterated, but was finally detected by a thin, black line, and separation was accomplished with the finger. Even after the separation of the lower lobe, no marked difficulty with respiration occurred, it was assumed, therefore, that the upper lobe was probably adherent. A large kidney clamp was put on the pedicle to the lower lobe and clamped tightly. Four small clamps were left on bleeding adhesions which were difficult to tie without consuming a considerable amount of time. The lobe was then removed. At that time, it was evident that the adhesions between the upper lobe and the chest wall had been very delicate and had been separated during the manipulation necessary to remove the lower lobe. The clamps were left in place and gauze was packed into the wound. The time of the operation was fifty minutes. The anesthetic was nitrous oxid and oxygen. Immediately after the operation, the pulse rose to 150, respirations, 26, temperature, normal. The pulse rapidly decreased to 110, but, during the next few days, the respirations continued to increase in number, and the pulse remained high, averaging about 120. Morphine was given liberally. The clamps were removed on the third day after operation without hemorrhage. September 29, coarse bubbles and a friction sound were heard all over the right side, from the fourth rib down. Leukocytes increased to 15,000 and finally to 27,000. Death occurred, September 29. Irrigation of the pleural cavity with Dakin's solution had been attempted early, but it seemed to cause marked discomfort to the patient. It had, therefore, been abandoned, with the expectation of continuing it later.

*Autopsy*—The upper lobe of the left lung was found to be entirely free, and there was, therefore, generalized infection of the left pleural cavity. In addition, there was fibrinopurulent pericarditis. The right lung was edematous.

*Comment*—In reviewing this case, it seems apparent that the patient would have had a better opportunity to survive if there had been firm adhesions between the upper lobe and the chest wall. The advantages would have been those which have already been enumerated in the text above. This case illustrates in a forceful way the importance and desirability of having adhesions between the unaffected portion of the lung and the chest wall.

*Case 3*—A man, aged 29, entered Barnes Hospital, March 11, 1922. He was referred by Dr. V. P. Blair who had corrected a facial defect. He gave a history of pneumonia in 1918, when he was with the American Expeditionary



Forces Pneumonia followed a shell wound involving chiefly the face. There was no wound of the thorax. Following the pneumonia, fluid was obtained several times from the chest by aspiration, but no operation was performed. A cough had been present ever since that time. He now coughed up from about 300 to 400 cc of sputum a day. This had a very foul odor, was thick and heavy, and the patient stated that it looked like pus. He frequently had slight fever and chills. Since returning from France, he had spent his time constantly in hospitals. There was rather marked clubbing of the fingers and toes. The physical signs were not striking, but indicated that the involvement



Fig 7 (Case 3) —Resected lobe

was in the right lower lobe. There was slight impairment of the percussion note on the right side, from the third rib down. Breath sounds were slightly suppressed over the right base. The roentgenograms revealed a shadow just to the right of the sternum in the lower thorax, which suggested slightly an abscess. Aspiration of this suspicious area with a needle revealed nothing. A bronchoscopic examination by Dr. Arbuckle disclosed no foreign body and indicated that the pus was apparently coming from the right lower lobe. March 18 Dr. I. I. Singer performed an artificial pneumothorax, 400 cc of air was injected into the right pleural cavity, changing the pressure from a former

one of from —6 to —4 to one of from —5 to —2 During the next two days, the patient raised more sputum than before, but he complained of some discomfort in the right thorax March 22, roentgenograms demonstrated that there was not a satisfactory collapse of the lung The question of radical operation was discussed with the patient, and he was acquainted fully with its dangers and possibilities In arriving at a decision for operation, he informed me he would much rather be dead than remain alive in his present condition, that he was, therefore, willing to take any chance, no matter how great, to become well

*Operation*—April 8, a first-stage operation was performed similar to that described in Cases 1 and 2 except that the pleura was opened in order to inspect the conditions present The lower lobe was found to be dark blue The upper and middle lobes were of normal color The lower lobe was adherent to the diaphragm and to the pericardium by strong fibrous adhesions It was much more solid to the touch than the upper two lobes There were no adhesions between the upper and middle lobes and the chest wall The lower lobe was, therefore, packed off with petrolatum gauze after the adhesions were liberated, in order to delay the rest of the operation until after adhesions had formed between the upper part of the lung and the chest wall The packing was removed, April 13, under nitrous oxid anesthesia The wound looked clean The middle lobe was clearly adherent to the lateral wall There was still a large space between the pericardium and lung which was not obliterated The lower lobe looked small, and still appeared to be isolated nicely Two Carrel tubes were inserted into the cavity to prevent infection by irrigation More gauze was put in loosely in order to overcome a slight degree of dyspnea which occurred after the removal of the packing During the next three weeks, the wound became clean, and remained so The patient became comfortable after a temporary period of discomfort One month after the first stage, he was given a transfusion of 550 c c of blood, preliminary to the lobe resection The transfusion was performed because the patient had a slight secondary anemia (hemaglobin, 80 per cent) On the day following the transfusion, the resection was carried out The lower lobe was found to be densely adherent, and the separation was extremely difficult because of the dense adhesions to the diaphragm and the pericardium Some tearing of the lung occurred during the separation and there was hemorrhage to the extent of about 250 c c Two large curved clamps were placed on the hilum, which immediately controlled the bleeding The lobe was then cut away No sutures or ligatures were placed, except three silkworm sutures through the skin The wound was packed lightly with petrolatum gauze The duration of the operation was thirty minutes Anesthesia was accomplished under nitrous oxid and oxygen, by Dr Hawthorne Immediately following the operation, the patient was again transfused He received 700 c c of blood Two days after the operation, an attempt was made to remove one of the large clamps, but bleeding occurred and the clamp was reapplied For the first three days the patient's condition seemed to be excellent On the fourth day after operation, however, he had a severe chill, which lasted for fifteen minutes He died on the fifth day following the resection with a temperature of 104 F, which had been present for twenty-four hours Previous to that, the temperature and pulse had been nearly normal

*Necropsy*—A partial necropsy was permitted, but not until after the body had been embalmed An extensive lobular pneumonia was found, involving both the right and the left lung

## SUMMARY

In advanced cases of bronchiectasis, the only method which seems to offer a chance of complete relief from all symptoms is a resection of the affected portion of the lung. The mortality has been high in the few cases reported. The literature contains records of forty-eight cases, with a total operative mortality of 52 per cent. It is probable, however, that improvements in method will greatly reduce the mortality. Even with this high mortality, the striking results obtained in the successful cases seem to justify the risk incurred in properly selected cases. The unspeakable misery of patients with advanced bronchiectasis leads them often to grasp at any straw which offers relief, regardless of the risk involved. It has been difficult in some of our cases to refuse operation when we have felt that the proper indications were not present.

# LUNG ABSCESS \*

G J HEUER, M D, AND P M MACCREADY, M D  
CINCINNATI BALTIMORE

In the records of the Surgical Service of the Johns Hopkins Hospital, there are sixty-two cases of lung abscess. It is our purpose briefly to summarize these cases in order to present to you what our experience with lung abscess has been.

Etiologically, these cases may be divided into four groups.

1 Thirty-one cases followed pneumonia associated with, or unassociated with, empyema.

2 Sixteen cases were postoperative, in the sense that they followed a postoperative bronchopneumonia or the aspiration of some infectious material. Four cases followed tonsillectomy, seven, intra-abdominal operations, two followed mastoid operations, and one, each, a hernia, an open reduction of a fracture and a breast operation.

3 Seven cases followed acute abdominal infections, of which four were liver abscesses secondary to acute abdominal infections, one a pelvic peritonitis, and two subphrenic abscesses secondary to appendicitis.

4 Eight cases followed a miscellaneous group of conditions. Two followed the aspiration of a tooth, two the perforation into the lung of an esophageal carcinoma, one an abortion with septicemia, and three a septicemia secondary to acute osteomyelitis, multiple arthritis and umbilical cord infection.

These four groups of cases will be considered in more detail.

## GROUP 1—POSTPNEUMONIC GROUP—THIRTY ONE CASES

Of these thirty-one cases, four were not recognized during life. In these, pneumonia was followed by empyema, which obscured the diagnosis. These patients were operated on for empyema and died. Necropsies in all showed bilateral multiple lung abscesses, conditions which could not have been satisfactorily treated by surgery.

In the remaining twenty-seven cases in this group, the diagnosis of lung abscess was made. The abscesses occurred in the right upper lobe in five cases, in the left upper lobe in two cases, in the right lower lobe in eight cases, in the left lower lobe in ten cases, and were multiple in the right lung in two cases. The condition was associated with empyema in ten cases and was not associated with empyema in seventeen cases.

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\* Read before the American Association for Thoracic Surgery, Washington D. C., April 29, 1922.

The treatment carried out in these twenty-seven cases was as follows. In twenty-two cases, a simple drainage operation was performed, either in one or two stages. In one case, an exploratory thoracotomy was followed by artificial pneumothorax. In one case, a drainage operation was followed by a lobectomy. In three cases, postural treatment by Garvin's method was tried.

Following these various forms of treatment, six patients died, a mortality of 22.2 per cent. Five patients died after drainage operations, and in four of them a necropsy was obtained. In three, the necropsy revealed multiple lung abscesses, only one of which had been drained at operation. In one, the necropsy revealed an acute spreading gangrene, which involved the entire right lung. One patient died after a lobectomy performed some months after a drainage operation. Necropsy demonstrated that death was due to an extensive bronchopneumonia.

Of the twenty-one patients who recovered, all were discharged from the hospital practically free from symptoms. In twelve, we know the late result. Ten are well from one to ten years after operation, entirely without symptoms. Two are active and consider themselves well, but it is evident that they have some cough and expectoration. In nine, we do not know the late result, but the study was not begun until recently, and we have hopes of tracing some of these patients.

Of the four patients treated either by artificial pneumothorax or by postural methods, we know the late result in two. One is perfectly well, one still has some cough and expectoration but considers himself so well that he does not need further treatment.

#### GROUP 2—POSTOPERATIVE GROUP—SIXTEEN CASES

Of these sixteen cases, five were not recognized during life. Two patients died some time after mastoid operations, one died after a gastro-enterostomy, one after an enterostomy, and one after an open reduction of a fracture of the femur. Necropsies in all revealed multiple lung abscesses.

In the remaining eleven cases, the diagnosis of lung abscess was made. The abscesses occurred in the left upper lobe in two cases, in the right lower lobe in four cases, in the left lower lobe in three cases, and in two cases they were multiple. The condition was not associated with empyema.

The treatment carried out in these eleven cases was as follows. In six cases, a simple drainage operation was performed. In four cases, exploratory thoracotomy was followed by artificial pneumothorax. In one case, no treatment was permitted, the patient refusing operation.

Three patients died following drainage operations. In two of the three cases, necropsies were performed, which revealed multiple lung abscesses, only one of which had been drained.

Of the eight patients who left the hospital, seven were free from symptoms, while one left the hospital untreated. In four cases, we know the late result. One patient is entirely well, several years after collapse treatment, three are in good health, two or more years after operation, but are not entirely well, as indicated by cough and slight expectoration.

Of the four patients treated by collapse therapy, only one has been heard from. He is perfectly well.

#### GROUP 3—ABDOMINAL INFECTIONS GROUP—SEVEN CASES

Of these seven cases, two were not recognized during life. One patient died some time after an operation for liver abscess, and one after an operation for peritonitis and subphrenic abscess. The symptoms and signs of lung abscess were not clear. Necropsies in both cases revealed multiple lung abscesses.

In the remaining five cases in this group, the condition was recognized and treatment instituted. The abscess occurred in the right lower lobe in four cases, and in one, it involved almost the entire right lung. The condition was associated with empyema in one case and was unassociated with empyema in four cases.

The treatment carried out in these five cases was drainage in one or two stages. Following operation, one patient died. Necropsy revealed a healed liver abscess and an enormous lung abscess involving almost the entire right lung.

The four patients who recovered left the hospital practically free from symptoms. In two, the late result is known, and these two patients are entirely well, two or more years after operation. Two patients have not been heard from.

#### GROUP 4—MISCELLANEOUS GROUP—EIGHT CASES

Of these eight cases, three were not recognized during life. One patient died some time after an operation for acute osteomyelitis, one after the drainage of several joints, and one after the drainage of an empyema. All showed, at necropsy, multiple lung abscesses.

In the remaining five cases, the condition of lung abscess was recognized. The abscess occurred in the right lower lobe in four cases and in the left lower lobe in one case. It was associated with empyema in one case, and unassociated with empyema in four cases.

The treatment carried out was drainage in one or two stages in three cases and lobectomy in one case. One patient refused operation or other treatment.

Following operation three patients died. Necropsies in these three cases revealed an extensive carcinoma of the esophagus with extension into and with the formation of, lung abscess in two. One patient, in whom lobectomy was performed, died of a pleural infection.

The late result in the two patients that left the hospital is not known at present

#### SUMMARY

1 Of sixty-two cases of lung abscess in our surgical records, fourteen were unrecognized during life. Necropsies in these fourteen cases revealed, in every instance, multiple small abscesses scattered throughout the lungs, conditions which could not have been satisfactorily treated by surgery.

2 In the remaining forty-eight cases, lung abscesses were recognized. In these, the abscess or abscesses followed pneumonia in twenty-seven cases, they were complications following some surgical operation in eleven cases, they followed acute abdominal infections in five cases, and were complications of a miscellaneous group of conditions in five cases. The abscesses occurred in the right upper lobe in five cases, in the left upper lobe, in four cases, in the right lower lobe, in twenty-one cases, in the left lower lobe, in fourteen cases, and were multiple in four cases. The abscesses were associated with empyema in twelve cases and were not associated with empyema in thirty-six cases.

3 The treatment of these forty-eight cases consisted of (a) drainage in one or two stages in thirty-six cases, (b) drainage followed by lobectomy in two cases, (c) exploratory thoracotomy and collapse therapy in five cases, (d) postural treatment (Garvin's method) in three cases, and (e) no treatment in two cases.

Forty-three patients, therefore, were subjected to forty-five operations. Following operation, there were thirteen deaths, an operative mortality of 28.8 per cent. Eleven deaths followed drainage operation, and necropsies in these eleven cases showed that (a) in six cases, there were multiple pulmonary abscesses, only one of which was drained at operation, (b) in one case, there was a consolidation, with softening and abscess formation involving the entire lung, (c) in one case, there was an acute spreading gangrene involving the entire lung, (d) in one case, there was an extensive bronchopneumonia in addition to the abscess, and (e) in two cases, there was an extensive inoperable carcinoma of the esophagus, with extension into the lung and with abscess formation.

Two deaths followed lobectomy, performed some months after a drainage operation. Necropsies revealed that one death was due to an extensive bronchopneumonia and the other to a pleural infection—not the result of leakage from the bronchial stump, but presumably the result of tearing into an infected lung during the separation of adhesions.

4 The end-results in the thirty-five patients who recovered and who were discharged from the hospital have not yet been so thoroughly worked up as they will be. At the present time, however, they are

as follows (a) Of the twenty-five patients who recovered following drainage operations, eleven have been well from one to ten years or more—entirely without symptoms, four have not been entirely well from one to ten years—they have some cough and slight expectoration Ten have not yet been heard from (b) Of the five patients who recovered following exploratory thoracotomy, plus collapse by artificial pneumothorax, two have been well from one to ten or more years, three have not yet been heard from (c) Of the three treated by postural methods (Garvin), one is not entirely well, having still some cough and expectoration, and two have not been heard from (d) Of the two patients who refused operation or other treatment, neither has been heard from

Such, then, has been our experience with lung abscess as it has occurred in a general surgical service There has been no attempt to eliminate any cases nor to gloss over our results Our experience simply demonstrates that lung abscess as seen in a general service occurs as a complication of many conditions and presents itself in a variety of forms As has been shown, it may be overshadowed by other conditions and escape recognition (fourteen cases), later presenting itself at necropsy in the form of numerous small scattered abscesses quite unfavorable from the standpoint of surgical treatment It may be recognizable, but it may occur in multiple form so as to defeat our surgical efforts—as in six of our cases It may be a complication of a hopeless condition, as in our two cases of carcinoma of the esophagus, in which the only justification for surgical treatment was the hope of relieving the patient of distressing cough, foul sputum and sepsis Undoubtedly, surgery at the present time achieves good results only in those single, well-circumscribed abscesses in which the condition of which they are a complication has disappeared If we consider only these as lung abscesses amenable to surgical treatment, then our results are vastly improved If we eliminate from our series the cases of multiple abscesses, and those with some serious intra-abdominal or mediastinal condition present at the time operation for lung abscess was performed, in other words, if we confine ourselves to the single, well-circumscribed abscesses in otherwise healthy individuals, then we have twenty-nine cases of lung abscess treated by drainage, in one or two stages in twenty-four cases, and by exploratory thoractomy followed by artificial pneumothorax in five cases—with one death from spreading gangrene of the lung, a mortality of 3.4 per cent The late results in these selected twenty-nine cases are Thirteen patients are entirely well, three patients are not entirely well, as they have some cough and slight expectoration, and eleven patients have not yet been heard from

Let us conclude with two remarks on our personal experience in the treatment of lung abscess A partial artificial pneumothorax



followed by roentgenograms of the thorax to determine, in doubtful cases, the presence or absence and the location of adhesions to the parietal pleura would seem a safe and helpful procedure. Stripping the parietal pleura from the thoracic wall over the point of approach, we have found to be a very useful preliminary step in the drainage of lung abscesses. It enables one to explore the lung over a considerable area, in order to determine to what extent adhesions are present and the location of the best point to open the abscess. It better enables one to fix the lung to the parietal pleura if adhesions are absent.

A study of our late results so far as they have gone demonstrates that it is the old, long-standing chronic lung abscess, with thick fibrous walls, which is often not entirely cured by drainage operations. The patients in our series that we know are well are those with acute or recent lung abscesses. The four patients that we know are not entirely well all had chronic abscesses of from two to seven years' standing which at operation presented thick fibrous walls.

# THE INTERRELATIONSHIP AND END-RESULTS OF CHRONIC SUPPURATIVE DISEASES OF THE LUNGS \*

WILLIS S LEMON, M D

ROCHESTER, MINN

The end-results of acute or chronic disease of the lung may be classified into (1) resolution to normal conditions, (2) fibrosis, and (3) necrosis. Which of these may be the end-result of any illness depends on the factors of resistance and the character of the noxa, chemical, bacterial or mechanical, that has been the causative agent in the production of the malady. Thus, come into being the three main diseases that constitute the suppurative type of pulmonary disease, namely, empyema, bronchiectasis and abscess. Acute pulmonary disease which proceeds into chronic disease may be classified into seven groups.

Group 1 Acute fulminating inflammations that may be caused by irritating gases, these rapidly fuse with later groups unless death ensues.

Group 2 Acute streptococcal bronchopneumonia, common during the epidemic of influenza.

Group 3 Less acute, but almost equally fatal, pseudolobar pneumonia, also of streptococcal or pneumostreptococcal origin.

Group 4 Pneumonia progressing to the formation of free or interlobar encysted empyema.

Group 5 Abscesses of the unilocular or multilocular type, or acute bronchiectasis. Included in this group are abscesses of embolic origin, and the aspiration type of bronchiectatic abscess.

Group 6 Residual inflammation which develops into chronic non-tuberculous infection of the lung, or into frank bronchiectasis.

Group 7 A resolving condition gradually reverting to normal.

In Group 4 are the greatest number of patients whose conditions are of long standing, and whose deformities and disabilities we are most often called on to treat. I have observed many such patients within the last three years, and almost invariably a fistula discharging pus gives evidence of former operation. If there is much granulation tissue in the sinus and projecting from it into the chest wall, the

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\* From the Section on Medicine Mayo Clinic

\* Read before the American Association for Thoracic Surgery, Washington, D C April 29 1922

discharge is more or less bloody There are five explanations of this chronicity

1 The treatment of tuberculous empyema by open methods, or by methods designed for the treatment of nontuberculous forms Hedblom<sup>1</sup> and McKinnie<sup>2</sup> have outlined the necessary precautions to be used in conditions such as tuberculous empyema, from the standpoint of both diagnosis and operation The latter says, "Assuming a purulent effusion of the pleura, not definitely metapneumonic or post-influenzal, the greatest care should be used to exclude tuberculosis before instituting open drainage, since cases of empyema showing no tubercle bacilli almost universally heal promptly, while those having tubercle bacilli rarely do so " Even with the utmost care, however, errors in diagnosis will be made, and untoward results will probably follow in a small proportion of cases representing a diagnostic error which by care may be reduced

2 The sinus itself may lead from infected tissue, have thickened walls and remain open indefinitely

3 At the base of the sinus there may be an infected rib, and osteomyelitis may be the cause of chronicity

4 The drainage may have been insufficient

5 The surgical wound may have been made in an improper position

Inasmuch as all purulent effusions tend to form adhesions, whereas air and transudates do not, pockets are formed, the pleura is thickened and the lung does not expand properly to fill the pleural space Added to this, bronchial fistulas or multiple fistulas are obvious causes of chronicity Fibrosis is one of the end-results of infection The fibrosis may become sufficiently extensive to cover the lung with a coat of mail, effectually preventing reexpansion Thickened trabeculae give the appearance of fibrous bands invading the lung which is affected by inflammatory processes and constitute one of the three processes of general or massive fibrosis, namely, (a) fibrosis of the pleura associated with fibrosis within the lung, (b) fibrosis extending from the hilum, and (c) fibrosis within the lung, and proceeding throughout the interlobular septums or around the bronchi and vessels, or in the alveolar walls

Such a result must necessarily cause changes in the chest itself Patients are now under my observation who have unilateral shrinkage of the wall of the chest, with loss of mobility, obliterated interspaces, lowered shoulder and scoliosis, the convexity toward the sound side Besides this deformity, a resultant flattening and immobility of the

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1 Hedblom, C A The Diagnosis and Treatment of Tuberculous Empyema, Surg, Gynec and Obst 34 445-465, 1922

2 McKinnie, L H Tuberculous Empyema, J A M A 78 400-402 (Feb 11) 1922

diaphragm may be seen on fluoroscopic examination, the importance of which has not been sufficiently emphasized clinically. Fibrosis, whether tuberculous or nontuberculous in character, constitutes one of the agencies which produce changes in position of the mediastinal structures, the most obvious of which are the heart and the trachea.

One of the interesting accompaniments of suppurative disease of the lung is the peculiar deformity of the extremities. I have observed



Fig. 1—Appearance of patient at time of operation

all degrees from simple clubbing, or hippocratic deformity, to true pulmonary osteo-arthropathy, with the characteristic burring of the terminal phalanges and periosteal overgrowth extending far up the long bones of the upper and lower extremities. Clubbing of fingers is not necessarily confined to pulmonary disease, nor is it always bilateral. I have seen within the year, unilateral clubbing in a case of aneurysm of the innominate artery. Locke<sup>3</sup> has made the most complete

<sup>3</sup> Locke E. A. Secondary Hypertrophic Osteo-Arthropathy and Its Relation to Simple Club-Fingers. *Arch Int Med* 15: 659-713 (May) 1915

study of this condition from a statistical and roentgen-ray standpoint and has recorded cases that seem to be primary rather than secondary in character

In the unfortunate cases in which errors in diagnosis have been made and patients with tuberculosis operated on, amyloidosis or tuberculous meningitis has been a fatal complication. Such conditions must be reckoned with in operative procedures producing collapse of the



Fig 2—Appearance of patient, three months after operation, gain in weight of 40 pounds (18 kg)

lung in cases of unilateral tuberculosis, particularly if the disease has been of long duration

The case reported herewith is an illustration of the difficulty of diagnosis in long-standing chronic pulmonary suppuration, it also illustrates the benefit that can be obtained by surgical intervention

#### REPORT OF CASE

*History*—W R S, man, came to the clinic, Dec 13, 1921, complaining of pain in the chest, persistent cough, excessive sputum, hemorrhage and deformity of the fingers wrists and ankles. He had apparently been

powerfully built, but now showed evidence of severe and long-continued illness. He had had influenza three years before, during a time when the scarcity of physicians in his outlying country did not permit him to have careful attention. It was thought that the influenza had been complicated by pneumonia, there was a history of pain which could be construed as that of pleurisy. The primary illness kept him in bed for about five months, although he had partially recovered within the first few weeks. He had continued to be an invalid from that time. A profuse hemorrhage had occurred September 16, and again



Fig 3—Thickened cortex in the shaft of the femur, fused bony and periosteal changes

he was forced to his bed, where he remained for two months. For a long time, he had had increased temperature, which usually reached its height about 3 p. m. It had not been more than 100 F. since August. He had noticed clubbing of the fingers for the last two years. His wrists were crippled, and his feet swollen and stiffened so that he was unable to dress himself alone, or to walk.

*Examination*—The patient had come for examination in a wheel chair and continued to use it during the time he was under observation before operation. He was examined in this chair or on a couch to which he was carried. He was not weighed at the time of his first examination, but he had weighed 220

pounds (100 kg) in normal health. The blood pressure was 112 systolic, and 72 diastolic. The pulse was 132 and the temperature 100 F, at 3 00 p m. He showed evidence of advanced dental infection, but his tonsils apparently were normal. The hair was crisp, short, wiry and rather scant, and the skin was dry over the entire body, with some exfoliation over the face. The heart was large, the apex beat being 5 cm. outside the nipple line. The chest was remarkably asymmetrical, the deformity consisting of flattening of the entire right side with absent Litten's sign, almost fixed diaphragm and very limited respiratory excursion throughout the right side. The percussion note over the

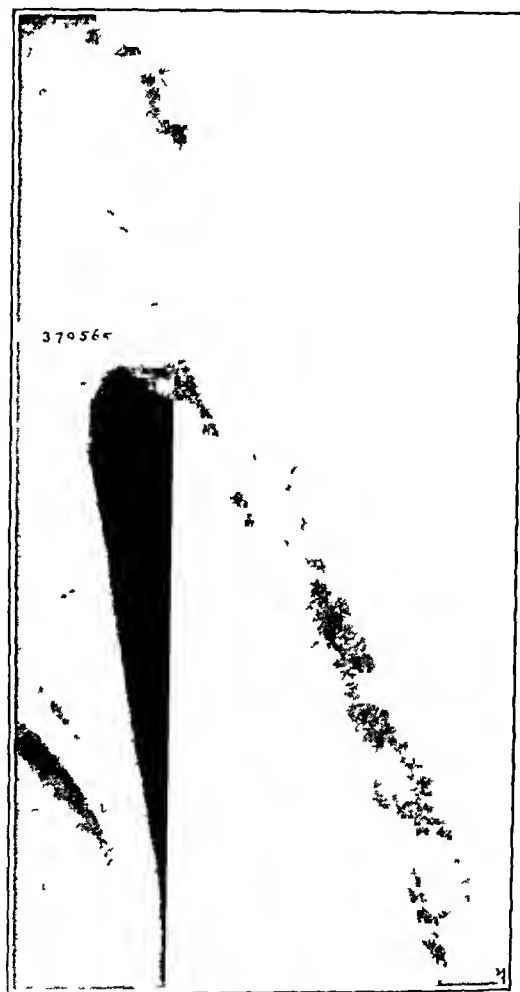


Fig 4—Porosity of lower third of humerus

chest was dull, but moist râles could be heard throughout, although the breath sounds were distant. He had arthritis in both knee joints. The femur on the right side was remarkably enlarged, there was limited movement in the ankle joints and noticeable hyperextension of the fingers. Roentgenograms of the chest revealed empyema on the right side, with a shadow resembling fluid which reached the level of the second rib in front. Roentgenograms of the bones revealed evidences of slight arthritis, marked proliferative osteitis in the hip joints and proliferative osteitis of the bones of the extremities. The history and examination pointed to the subjoined conclusions with regard to the chronology of the infection.

Influenza had occurred, complicated by bronchopneumonia, with succeeding empyema. The empyema cavity had formed a fistula with the bronchus, and continuous expectoration of large amounts of purulent material had resulted.

*Operation and Result*—Operation was performed December 20, and 275 cm of the seventh rib was resected. After several attempts, pus was aspirated by needle, the tract running inward and slightly upward to a depth of about 75 cm from the pleura. Free pus was not found in the pleural cavity itself although the parietal pleura was thickened. By blunt dissection along the



Fig 5—Roughened cortex due to periosteal proliferation

course of the needle, a cavity was opened, about 8 or 10 cm in diameter, containing pus mixed with blood. The cavity was sponged out and explored by the aid of a small light, placed inside. The cavity was so deep, however, that the walls could not be seen. The surgeon was of the opinion that he was dealing with a deep-seated abscess of the lung. The patient coughed up considerable bloody material at the time of operation, but, after the institution of drainage, there was no further coughing. The wound was treated in the usual manner. About three weeks later the drainage tract was dilated and three tubes were again inserted.



The patient recovered uneventfully, and was markedly improved. He was able to walk without help, he no longer coughed, the amount of sputum was reduced practically to nothing, and he gained about 40 pounds (18 kg) in weight before his dismissal.

#### COMMENT

This case is an illustration of the fact that if patients continue to be ill after the primary infection should have been overcome, it must be assumed that they are suffering from suppurative disease which should be attacked at once. The case also illustrates the importance of the surgeon's exact knowledge of the anatomy of the lung, the pleura



Fig 6—Rarefaction of head of tibia, periosteal proliferation of the shaft of femur

and of the interlobar markings, because such suppuration may be found in any location in which two surfaces of pleura meet. Although a surgical diagnosis of abscess was made in this case, the possibility was considered of encapsulated empyema lying deep between the lobes, and forming with the bronchus a fistula which provided the profuse drainage seen at the primary examination.

Because of the fibrosis and the persistence of cough, particularly in patients who have developed bronchial fistula, even if successful operations have been performed, bronchiectasis must be reckoned with. This is true for two reasons: first, because the strength-giving wall of the

bronchus itself may have been primarily involved in the original disease of the lung, as almost invariably occurs in diseases of influenzal origin, and, therefore, gives way under the added pressure due to cough, and, second, in the fibrous lung the damaged bronchus has lost its normal elastic support and dilates when the interbronchial pressure is raised (McPhedran<sup>4</sup>) This result is more likely to follow when the pleura

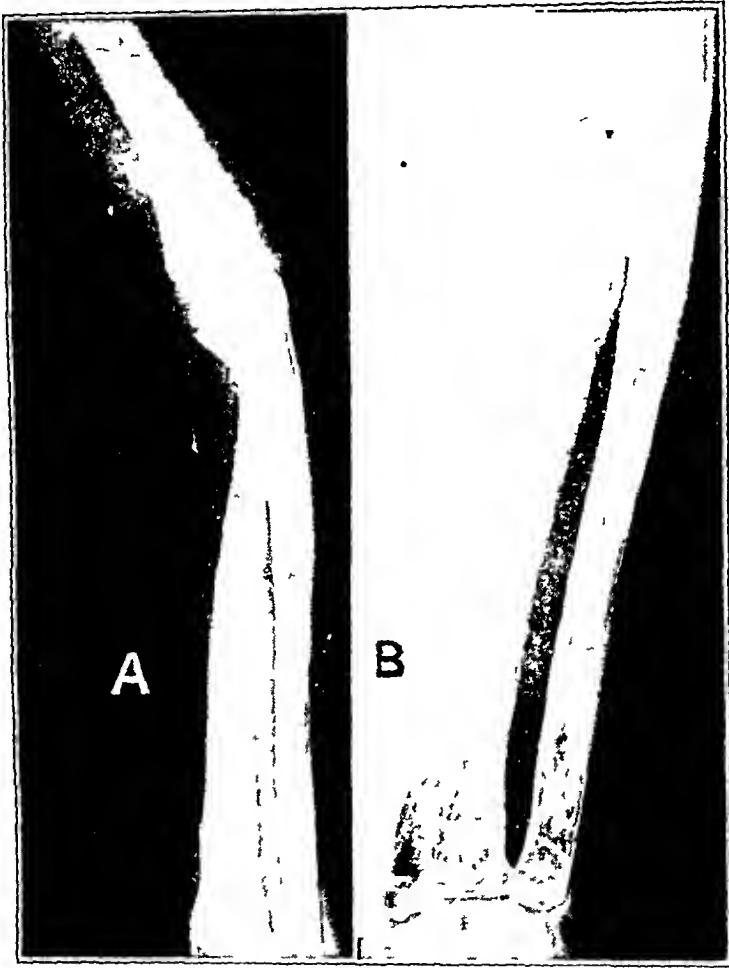


Fig 7—*A*, periosteal proliferation, *B*, porosity at distal ends of radius and ulna

anchors the lung to the chest wall, a condition present in the majority of my patients suffering from bronchiectasis Hoover says, however

It seems probable that, in cases of bronchiectasis accompanying fibroid disease, destructive inflammatory process of the bronchial wall is the primary lesion That the idea of a tractive diverticulum may have some merit can be granted, but it is not susceptible of direct proof

<sup>4</sup> McPhedran, A Diseases of the Bronchi, in Osler and McCrae Modern Medicine, Philadelphia, Lea and Febiger 2 881-944, 1914

There are two other factors which may enter into bronchiectasis. One is traction on the bronchi from inspiratory movement of the thorax, and the other is an increase of endobronchial pressure which accompanies effort at coughing. That the endobronchial pressure is raised with the effort of coughing is evident enough, but, if endobronchial pressure is to explain bronchiectasis, then extrabronchial pressure over the site of bronchiectasis must be very much less than the endobronchial pressure during the act of coughing. If endobronchial pressure does not exceed extrabronchial pressure in the expiratory effort, the act of coughing could not contribute to dilatation of the bronchi.

In my experience with influenza, bronchiectasis did not develop for six months or a year after the acute illness. In only one instance



Fig 8—Flexion deformity, osteoporosis

could a diagnosis of acute bronchiectasis be made with accuracy. The time required was made necessary by the disintegration of the integrity of the bronchial wall and the subsequent formation of fibrous tissue.

Norris and Landis<sup>5</sup> say

In regard to pulmonary fibrosis and bronchiectasis, it is not a question of distinguishing between them but of determining whether the two conditions are associated. Both are due to the same cause. In about 80 per cent of the

<sup>5</sup> Norris, G. W., and Landis, H. R. M. *Diseases of the Chest and the Principles of Physical Diagnosis*, Philadelphia, W. B. Saunders Company, 1920.

cases of massive fibroids, the bronchi are dilated. Rarely the bronchi are dilated without associated interstitial changes in the pulmonary tissue. In a case with marked unilateral retraction of the chest wall, there are also a paroxysmal cough, profuse expectoration, often of a foul odor, and marked clubbing of the fingers. It is reasonably certain that in addition to the fibroid changes the bronchi are also dilated.

It is important to recognize the relationship between abscess and bronchiectasis because often the abscess in the process of healing may



Fig 9—Fluid level at second rib, right costophrenic angle obliterated, left costophrenic angle free

provide conditions that are necessary for the production of bronchiectasis, and, alternately, by the occurrence of acute infection to which sufferers from bronchiectasis are prone, abscess may develop. Bronchopneumonia is not an unusual complication of bronchiectasis. I have known it to occur repeatedly in several of my patients. The end-results vary only slightly from those of empyema, inhalation may produce a

septic bronchopneumonia-gangrene in the lung tissue. Abscess of the brain is not an uncommon complication, and amyloid changes appear in the liver and kidneys.

Improvement in bronchiectasis may occur even in severe cases, whether unilateral and treated by operative collapse or bilateral and under medical management. Conner<sup>6</sup> has recently studied a patient



Fig 10—Condition of lung one month after operation

with bilateral bronchiectasis who had an unusually large amount of chylous sputum and who improved remarkably under medical management. Hedblom<sup>7</sup> has operated in unilateral cases, with very encouraging results.

A subgroup of cases of suppuration of the lung, classified as non-tuberculous infections, is fully described in the literature. The cases

6 Conner, H. M. Personal communication.

7 Hedblom, C. A. Personal communication.

that have been observed in the Section on Diseases of the Chest in the Mayo Clinic have been studied recently by Conner<sup>8</sup> He has summarized the opinion of the section as follows

The chief points in the diagnosis of nontuberculous infection of the lungs are (1) cough for a prolonged period, either constant or with exacerbations, (2) little depreciation of general health, (3) little if any fever, and, if present,



Fig 11—Position of drainage tubes

intermittent, (4) lack of progression of the disease, (5) location of the lesion usually in the base of the lung, and (6) absence of bacilli of tuberculosis in the sputum

Nontuberculous infection of the lungs may be distinguished from tuberculous infection mainly by the location of the lesion in the base, by the less marked or absent depreciation in health, by lack of progression, and by the absence of bacilli of tuberculosis. Often there is leukocytosis. In at least nine of ten

<sup>8</sup> Conner, H. M. Nontuberculous Infection of the Lungs, *Minn Med* 5:364 (June) 1922

cases of tuberculosis, the infection is found in the upper lobes or apices, while almost the reverse is true of these cases. Recently, Rosenblatt reported that in 1,000 cases of tuberculosis, only three were primarily in the base of the lung. Seventeen of eighteen patients presenting basilar lesions admitted to the Bedford Hill Sanitarium with the diagnosis of tuberculosis were found to be nontuberculous. In this connection, it is well to remember the dictum of Brown that "abnormal physical signs at one apex should be considered as due to pulmonary tuberculosis until proved not to be, while those at the base should be looked upon as not tuberculous until definitely proved so."

Nontuberculous infection of the lungs is differentiated from simple chronic bronchitis by the fact that chronic bronchitis is usually generalized, is often secondary to cardiac or other disease, has less tendency to the production of purulent sputum, usually does not cause exacerbation of symptoms with increased temperature, and usually produces no leukocytosis. Moreover, in simple bronchitis, the râles are predominantly dry, while in this condition they are predominantly moist.

Bronchiectasis may usually be distinguished from nontuberculous infection of the lungs by clubbed fingers and more abundant foul sputum brought up by paroxysms of cough. Cough and expectoration are usually markedly affected by changes of position, such as lying and stooping. The cough in bronchiectasis is typically loose and a copious amount of the sputum can usually be produced by inversion. On standing, the sputum often separates into three layers. There is usually no leukocytosis in bronchiectasis.

Bronchopneumonia is usually bilateral, acute, and not recurrent, while this condition is chronic, often unilateral and recurrent. In bronchopneumonia, there are usually some signs of consolidation, while in this condition such evidence is usually absent.

In adults, the prognosis must be very guarded, as it is likely that the condition will persist or recur. It seems quite probable that most of these patients will develop a true bronchiectasis if the infection persists. In children, the prognosis is somewhat better, according to most authors, although I have not had much experience with such cases.

#### CONCLUSIONS

1 Nontuberculous infection of the lung is a nonspecific disease, which, however, deserves a name as a separate disease entity.

2 The essential features are cough, marked chronicity, exacerbations, little or no fever, and few other constitutional symptoms, usually purulent expectoration, lack of progression and location of the lesion almost always in the bases.

3 The principal physical sign is moist râles.

4 Diagnosis is made mainly by chronicity of cough, little effect on general health, location of signs in bases, and persistent absence of bacilli of tuberculosis.

5 In the differential diagnosis, chronic bronchitis, tuberculosis, frank bronchiectasis and bronchopneumonia must be considered.

6 Prognosis must be guarded in adults.

7 Treatment is mainly by posture.

#### SUMMARY

Abscess of the lung resulting from pneumonia represents the result of the patient's failure to react effectively. It is the consequence of death of tissue, and, instead of subsequent fibrosis, necrosis is the pathologic picture.

Abscess may so simulate encysted empyema with bronchial fistula as to be indistinguishable. In fact, it may be true that certain abscesses not postsurgical, may be of such a character. This is the opinion of Ashhurst,<sup>9</sup> and it certainly may be true in conditions which were preceded by an influenzal infection. Again, abscess may constitute the primary disease in empyema. Moschcowitz<sup>10</sup> is of this opinion, and Robinson<sup>11</sup> believes, that encapsulated forms of empyema are caused by the subpleural abscess. I have recently seen a patient whose empyema was almost certainly primary, and a small abscess in the lung secondary. This seemed so because of the histologic picture presented by the tissue around the abscess.

In many instances, the presence of empyema or of thickened pleura has made a diagnosis of abscess very difficult. Often in cases of long standing, even after operation, it has been impossible to distinguish abscess from empyema with bronchial fistula or from bronchiectasis. Only necropsy has shown the internist's and the surgeon's errors.

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9 Ashhurst, A. P. C. Surgical Experiences with Encapsulated Empyema and Abscess of the Lung. A Plea for Exploratory Thoracotomy, *Internat. Clin.* **4** 173-210, 1916.

10 Moschcowitz, A. V. Newer Conceptions of the Pathogenesis and Treatment of Empyema, *Am. J. M. Sc.* **159** 669-701 (May) 1920.

11 Robinson, S., quoted by Norris and Landis, Footnote 5.



# FIBROSIS OF THE LUNG FOLLOWING LIGATION OF THE PULMONARY ARTERY

COMBINED WITH PHRENICOTOMY AND WITH PARTIAL OCCLUSION  
OF THE PULMONARY VEINS \*

KARL SCHLAEPFER, M D

BALTIMORE

For the treatment of unilateral tuberculosis of the lung, two methods are now widely used, artificial pneumothorax and extrapleural thoracoplasty. These methods produce good results after a very long time, one year or perhaps several years usually being necessary to effect a cure. Special care has to be taken to improve the general condition of the patients, perhaps by residence in a sanatorium. The patients are unable to work during this period, hence, it is of great economic and social importance to shorten the time necessary to restore them to health.

Artificial pneumothorax and extrapleural thoracoplasty act indirectly. The lung is compressed from the outside, either by introducing a gas or a mass of fat or paraffin between the lung and the bony chest wall, or by bringing the chest wall into a state of collapse, as in extrapleural thoracoplasty. The second method has the disadvantage of causing an increasing deformity of the whole thorax, especially of the vertebral column. Both methods force the lung to decrease its physiologic action, the aeration of the venous blood brought in through the pulmonary artery being diminished. Hence, the circulation is altered. Stasis takes place, followed by extravasation of serum and blood corpuscles into the alveoli and the interstitial tissue of the lung. Secondary fibrosis occurs, with a tendency to shrinkage, as in all new fibrous tissue. The toxins of the foci of infection also are a strong stimulus to the formation of fibrous tissue. The two agents help each other in the endeavor to combat an infection.

A more efficacious therapeutic procedure is one which has a direct influence on the physiologic work of the lung, and which gives the diseased organ a rest, in order that it may be able to conquer a tuberculous infection. Such a procedure is found in ligation of the pulmonary artery of one lung or of one lobe. No venous blood comes to the alveoli of the compressed area. The arterialized blood in the pulmonary veins no longer is benefited by the impulse from the artery. The bronchial arteries, arising from the aorta or from the intercostal arteries, guarantee a sufficient supply of blood to the lung. Their

\* Preliminary report of experiments carried on during the winter of 1921-1922 in the Surgical Hunterian Laboratory of the Johns Hopkins University Medical Department

\* Read before the American Association for Thoracic Surgery, Washington, D C, April 29, 1922

communication with the pulmonary veins is essential to prevent sudden hemorrhagic infarct. A considerable stasis takes place, particularly on the alveolar side of the pulmonary veins, with resultant extravasation of serum, but also with extravasation of erythrocytes and leukocytes into the alveoli and the interstitial tissue. An increase in the flow of lymph occurs at the beginning, in an effort to prevent this process, but the stasis becomes more and more effective. The suction effect of the blood from the left atrium, and the action of the thoracic wall and of the diaphragm maintain the circulation. By paralyzing the diaphragm or cutting the intercostal nerves, or by a secondary extrapleural thoracoplasty, we can reinforce the effect of a primary ligation of the pulmonary artery. Wherever a chronic stasis is present in an organ, the edematous tissue mixed with extravasated blood is gradually replaced by fibrous tissue. This is especially true when the general condition of the body is not greatly affected and the stasis is not the result of general marasmus.

It is evident, then, that a lung becomes fibrous after ligation of the pulmonary artery. The edema acts as an irritant. A superimposed infection with formation of exotoxins increases this tendency, a fact which is of great importance in the treatment of chronic infectious diseases of the lung, especially tuberculosis. By ligating the pulmonary artery, we get a firm fibrosis of the lung in a probably shorter time than in artificial pneumothorax or in extrapleural thoracoplasty. The experiments of Bruns, Sauerbruch, Robinson, Willy Meyer and Kawamura have demonstrated this fact, and clinical application of the principle in a few cases by Sauerbruch, Kuttner and Willy Meyer prove that it is suitable also in cases of tuberculosis. In experiments on rabbits, I obtained the same results. A series of dogs is still under observation. The roentgenograms taken at different intervals reveal a marked increasing fibrosis. Phrenicotomy performed at the same time as ligation of the pulmonary artery is very helpful.

From my present findings, I believe that, by combining these two procedures, and by using the paralyzed diaphragm and the mediastinum as relative movable organs for the retracting lung, we shall obtain the greatest amount of fibrosis, and we shall be able to bring about healing clinically, even in very advanced cases of unilateral tuberculosis by encircling the foci of infection with a covering of dense fibrous tissue. Hence, the lung will also be prepared in a very careful way for a secondary lobectomy, and the patient will be able to recover after the first operation (ligation of the pulmonary artery), and endure much more easily a second lobectomy, which eliminates the tuberculous foci of infection, rendered quiescent by their fibrous envelop.

A second method of producing fibrosis of the lung by direct action is partial occlusion of the veins. Basing their opinion on the pathologic

findings, Rokitsansky and Tripiier pointed out that an organic heart lesion diminishes the tendency to tuberculosis of the lung. Eichhorst and Fraentzel restricted the application of this law, basing their opinion on their clinical experience in lesions of the left side of the heart. Tiegel proved experimentally the truth of the law that partial occlusion of the pulmonary veins of one side or of one lobe, followed later by intravenous injection of tubercle bacilli, makes the side or lobe of the lung so treated much less liable to infection than the side on which operation was not performed. By this operative procedure also, we secure stasis in the lung, with resultant edema and extravasation of blood. The inflow from the pulmonary artery meets an obstacle, which persists. The resulting edema has, within a few months, the same effect on the lung as ligation of the pulmonary artery. Fibrosis takes place, with a tendency to be most dense around the foci of infection, the toxins acting as increasingly powerful stimuli to this fibrous tissue formation. A series of dogs on which I made this occlusion are still under observation.

In patients having a slight infection on one side, with a family history of several cases, this procedure, carried out with a Halsted metal band, may be the procedure of choice. The stasis must be effective for at least several months. After taking off the band, later, the function of the lung could be partly restored. The effect of this procedure in a lung threatened by infection, when the organism shows diminished resistance, would be partly curative, partly preventive.

A third method of bringing a lung to functional rest would be blocking the air passage. This was done experimentally by Dr. Halsted, and then by Dr. Crowe at the Johns Hopkins University, who blocked the main bronchus of a lung with a piece of fascia. After a few months, a dense fibrosis of the resting lung had developed. The lung became much smaller. The bronchi were considerably enlarged, proportional to their size, and were filled with a homogeneous, jelly-like mass.

These are the three different procedures which cause fibrosis of the lung in the same way, by direct decrease in the physiologic function of the lung. Immobilization of the organ hastens the process. The results may be obtained in a relatively short time, probably shorter than by using the indirect methods of artificial pneumothorax and extrapleural thoracoplasty. Ligation of the pulmonary artery combined with phrenicotomy, or partial occlusion of the pulmonary veins, are methods which should be worked out clinically for cases of unilateral tuberculosis. The findings in the experiments, and a few clinical observations, encourage us to follow up this aid to thoracic surgery for the cure of patients suffering from chronic infectious disease of the lung, particularly tuberculosis of the lung.

# OBSERVATIONS ON LUNG SUPPURATION AND ITS TREATMENT

A BRIEF REVIEW OF PERSONAL EXPERIENCES AND CLINICAL IMPRESSIONS OBTAINED WITHIN THE LAST TWELVE YEARS \*

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The principal topics dealt with in this paper are

- I The nomenclature of lung suppuration
- II The results obtained with the help of the bronchoscope in the treatment of lung suppuration
- III The establishment of a lung lip-fistula in certain cases of bronchiectatic lung abscess

## ETIOLOGY

The etiology of suppurative inflammation of the lung is similar to that of pus formation in other parts of the body. That is to say, it is due to traumatism inclusive of the entrance of a foreign body, to the invasion of the pulmonary tissue by pus-forming microbes, the products of which are not absorbed, but form an abscess, to a specific inflammation of the chronic type (tuberculosis, syphilis), or, lastly, to the presence of, or the breaking down of, a benign or malignant tumor.

Fulminant, acute inflammation, subsequent to the sudden occlusion of a large branch of the pulmonary artery by a virulently infected embolus or to the aspiration of extremely septic material, which is likely to produce acute progressive gangrene and pus formation, also exceptional conditions, as actinomycosis and suppurating hydatid, are not considered here.

If, in the term "foreign body," we include also liquids, or in other words, if we substitute the word "substance" for "body," we may be right in asserting that the great majority of pulmonary suppurations, excepting, of course, tuberculosis and syphilis, are due to the entrance of a "foreign substance" into the bronchial tree and lung tissue. The bullet, pieces of clothing, bone-splinters, etc., that enter the organ in violent traumatism from without, through the chest wall, as well as "foreign substances" that enter the bronchial tree and lung tissue by aspiration through the mouth and the trachea, all tend to produce inflammation and suppuration.

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After some time has elapsed, the suppuration invariably involves the alveolar tissue of the lung, plus the communicating bronchi, the two structures within the lung which always represent a unit in a pathologic sense

The degree and rapidity of inflammation depend on the virulence of the bacteria that enter with the foreign substance, that is to say, on the infectiousness of the material. Of aspirated fluids, the principal representatives, according to clinical experience, are (1) stomach contents, aspirated during general anesthesia, stomach lavage, etc., (2) blood and mucus, mixed with semisolid or solid infectious material (plugs, tissue), aspirated in the course of nasopharyngeal operations, particularly tonsillectomy, or the removal of adenoids, and (3) infected water, aspirated while the person is swimming

It is also possible, and appears plausible, that the sputum, discharged from the alveoli during the course of the inflammation and the convalescence from typical pneumonia, is reaspirated from the bronchial tree with the paroxysmal deep inspirations following the coughing spells, and produces a postpneumonic lung suppuration. Such sputum may also be aspirated into hitherto uninfected parts of the lung in the act of expectoration and subsequent inspiration

In other instances, the pneumococci, or a microbic infection of a different type (streptococci, or other pyogenic bacteria), may directly produce a suppuration of the lung in the presence of nonresolution of the inflamed area

It is different with tuberculosis and syphilis, in which one or more tubercles or gummas break down, producing suppuration. And even there, it appears plausible to assume that the "spread" of the purulent inflammation is often due to aspiration, producing a slow or quick sequence of lobular pneumonic foci

The aspiration of pus and mucus from an abscess of the upper portion of the lung into other parts of the organ, particularly into the lower lobe, for example, during an extrapleural thoracoplasty in an operation for advanced pulmonary tuberculosis, or in an operation for nonspecific chronic suppurating disease of the lung, although belonging to this class, has a place of its own

I believe that the dreaded lung suppurations following tonsillectomy and the removal of adenoids are almost all due to aspiration of blood, mucus, particles of the infected glandular tissue or tonsillar plugs during the operation. The theory of lung infection subsequent to tonsillectomy by way of the blood stream seems far fetched and less plausible, although one or the other case may perhaps develop in this way

#### GROSS PATHOLOGY AND NOMENCLATURE

In the evolution of the subject of subacute and chronic lung suppuration, the discussion centers around typical subacute and chronic

lung abscess on the one side, and bronchiectasis on the other. The border line between the two conditions cannot be sharply drawn. Where does the pathologic picture of lung abscess end and that of bronchiectasis begin? It is hazardous for one not a pathologist to plunge into that question.

There is, at present, a great deal of confusion in the nomenclature of lung suppuration. Without entering into the details of the well known gross pathology of these affections, I should venture to say, from a clinical standpoint, that the "single" circumscribed cavity within the lung, that contains pus and nothing else, should be regarded as lung abscess, whereas a "multilocular" cavity formation with suppuration, which, on cross section, presents a honeycomb-like appearance, a purulent disease of chronic character, which had spontaneously attacked many places within one or more lobes of the lung, on one or both sides of the chest, before the patient had surgical or special treatment, represents bronchiectasis.

Of course, I realize that a true lung abscess can occur in multiple affections, for example, one single circumscribed cavity may occur in the upper and one in the lower lobe of the lung, just as we may find one abscess cavity in the left lobe of the liver and a second one in the right lobe.

Between the two classes are transitions which are seemingly difficult to classify. I have opened an abscess in the depth of the lung, in which, when palpating, the finger passed "around the corner"—the corner being formed by a projecting, partially broken down portion of the wall of the bronchus at its subdivision—and entered into a second smaller pus cavity. Both contained fibrinous coagulations with detritus of very foul odor. This is not a typical abscess, nor is it bronchiectasis. To my mind, it seems correct, clinically, to call such a cavity a "bronchiectatic lung abscess," that is, an irregular cavity, which evidently is the result of a local gangrenous inflammation of the lung, due either to aspiration and its consequences, or I believe, in rare cases, in which the history disproves aspiration as well as the breaking down of a gumma or of a tumor, to an infectious embolism of small caliber and low virulence. The cavity usually contains, as just stated, many round and irregularly shaped, very soft and friable masses, fibrinous coagulations of varying size, usually not larger than a marble, plus grumous material all of which have the same fetid odor as the sputum. Microscopically, these coagulations show necrotic tissue, blood clots and fibrin, containing many polymorphonuclear leukocytes and clumps of bacteria.

Clinically, I would then divide subacute and chronic nonspecific lung suppuration not due to traumatism nor to exceptional occurrences, such as actinomycosis into three classes.

1 *The Typical Lung Abscess*—This occurs usually subsequent to an attack of influenza or pneumonia, that means it is, in other words, an ordinary abscess, due to the breaking down of the tissue of the lung, which is attacked by the inflammation, and it has a tendency to heal after surgical evacuation

2 *Typical Bronchiectasis*—This is the multilocular cavity formation within one or more lobes of the lung—in exceptional cases, in both lungs—which, on section, presents a honeycomb-like suppurating appearance

### 3 *Bronchiectatic Lung Abscess*

In the typical bronchiectasis, the anatomic structure of the bronchial tree is primarily affected, but naturally the surrounding lung tissue is also involved later on, the intensity depending on the extent to which a mixed infection with its deleterious results has invaded these cavities

The more I have thought about this affection and seen it, the more I believe that it must be of congenital origin, at least in the greatest number of cases. We should best reserve the term bronchiectasis for this particular, typical lung affection. It will always be easily recognized as such pathologically, after one has once seen the remarkable specimen after removal, either at operation or necropsy (Fig 1). Clinically, it is found mostly in young persons who have had neither pneumonia nor influenza or submitted to any nasopharyngeal or other operation under general anesthesia. It affects more often the lower lobe than the upper, and is found more frequently on the left than on the right side. The secretion of these abscess cavities may not necessarily be foul. Lately I have observed a young man, aged 17, who has been sick for more than two years. When asked to expectorate, he could fill, in the exaggerated knee-elbow posture, quickly and at will, more than half of a medium-sized pus basin. The secretion poured from his nose and mouth as in a vomiting spell, and it had no odor whatsoever. On examination of the same patient during operation, the surface of the lung was of the normal, yellowish-pink color. The presence of a pathologic condition was demonstrated only by a greater resistance to the examining finger. The pulmonal pleura was entirely normal and without adhesions.

The third class, the so-called "bronchiectatic lung abscess," should embrace all the other nonspecific and nontraumatic subacute and chronic lung suppurations which are so frequently found. The term well describes the pathologic picture seen after opening and evacuating the abscess. The observer perceives large and small open cavities, which communicate with the visible central defect, the former bronchiectatic abscess. When its contents are removed, any portion of the interior of the cavity, under good illumination, shows a picture not unlike that of the dilated pelvis of a kidney after removal of pus result-

ing from a pyonephrosis. If we take a plaster cast of a bunch of grapes of varying sizes, divide the cast lengthwise and remove the grapes, the cavity of such a half, "the negative," resembles to my mind the appearance of the cavity of what we have called "bronchiectatic lung abscess." Of course, we must imagine that in many places, and scattered throughout the inside, the cut surfaces of larger and smaller bronchi would appear.



Fig 1 (Case 17) —Lower lobe of the left lung of a boy, aged 6, with typical bronchiectasis, specimen divided longitudinally

In some of these cases, more than one cavity may be present, which cavities naturally communicate with, and empty their secretions through, that branch of the main bronchus through which aspiration took place, or which belongs to the area infected by a septic embolus. The second cavity may communicate with the first by a larger bronchus tract, and then drain to the surface sufficiently to heal (Case 2), or it may communicate with the first by means of a small bronchus, thus representing



a typical "hour-glass shaped" bronchiectatic abscess cavity. If the second also contains fibrinous coagulations, it will keep up the clinical symptoms of improperly drained lung suppuration and require special incision with drainage (Case 5).

The chosen nomenclature, bronchiectatic lung abscess, might be criticized, and perhaps rightly so. Etiologically, pathologically and clinically, this affection represents something different from typical bronchiectasis. There are no multiple cavernous distentions of the bronchial tree, with inflammatory affection and breaking down of the surrounding lung tissue. There is a total defect of bronchi, plus adjacent lung tissue, a larger cavity, the result of gangrene and expectoration of broken down lung tissue, which was healthy and normal before the inflammation had set in. The term nonprogressive local gangrene of the lung would cover the pathologic picture. However, it seems better, in order to keep in line with the accepted nomenclature of suppurative chronic lung disease, to call such a cavity a "bronchiectatic lung abscess," as long as we know and remember what the name implies.

#### DIAGNOSIS

Clinical and laboratory examinations, roentgenography and bronchoscopy combine to establish a more definite diagnosis. The typical lung abscess often shows the classical symptoms of cavity formation in the lung. On percussion, dulness is elicited if the abscess is in the depth and surrounded by infiltrated lung tissue, if nearer the surface, the sound is tympanitic (the positive coin sound, and the cracked pot sound when the patient opens the mouth). On auscultation, loud bronchial breathing is heard, with a difference in the voice sound, loud and whispered, and larger and smaller râles. The history, the short duration of the disease, elastic fibers in the purulent sputum, which is not very copious and which usually has a sweetish odor rather than the terribly foul odor often encountered make one suspect the presence of abscess.

The clinical findings may be trivial on percussion and auscultation in typical bronchiectasis. But the long existence of the trouble, often extending from childhood or adolescence, the copious twenty-four hour sputum, which, in rare cases, is odorless, although usually it possesses a terribly foul odor and at times is intermingled with bloody streaks, and does not contain elastic fibers, a sputum that shows three layers on standing, and, if involving the right middle or one of the lower lobes, frequently pours out of the mouth and nostrils in immense quantities when the patient places himself in a pronounced knee-elbow posture, the clubbed terminal phalanges of the fingers and toes should make the diagnostician consider this disease.

The diagnosis of bronchiectatic lung abscess requires, besides the classical clinical symptoms of a cavity, or cavities, a history of aspiration

or of sudden onset of the trouble at any time of the patient's life without traceable cause. The sputum is also copious and always very foul.

Stereoscopic roentgenograms present a beautiful plastic picture of diffuse density, but often fail to assist the surgeon in making the diagnosis of typical bronchiectasis. They are, however, of much value in cases of the typical lung abscess, as well as of the bronchiectatic lung abscess. Here they often demonstrate clearly the presence of one, or more, larger or smaller cavities, with a distinct fluid level.

Much remains to be done, it seems to me, by roentgenologists in this type of disease. They must learn, not only to determine the presence of an abscess, but also to localize more accurately the focus, and, if possible, the exact location of adhesions between the pulmonary and costal pleura. True, now and then they succeed in localizing correctly the seat of the trouble, telling us how many inches we have to measure from the spinous process of the seventh neck vertebra down, and how many from there to the right or left side, in order to find the spot where the aspirating needle should enter and strike the abscess. But these cases, up to date, are exceptions, and we are not advised so far at what depth we are likely to enter the cavity, how many inches below the surface of the thorax we may expect to find it.

It is to be hoped, and greatly to be desired, that roentgenologists will devote further thought and investigation to this subject, in order to give the surgeon the real assistance which he needs when proceeding with his operative work on conservative lines.<sup>1</sup>

If the surgeon is bent on lobectomy, a refined diagnosis is, of course, superfluous. All he might find it convenient to know before operation is whether one or more lobes are the source of the sputum.

Comparing at present the value of roentgenographic and specialistic assistance in establishing the accurate diagnosis of lung suppuration, a trained bronchoscopist certainly is the best friend of the surgeon. He will clearly localize the disease and indicate definitely which lobe is the only, or principal, source of the sputum. If a bronchoscopist is not available, or if the operator does not favor such specialistic examination, direct inspection and palpation of the lung after thoracotomy will give

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<sup>1</sup> A few days ago I received a communication from the roentgenologist of the Lenox Hill Hospital, Dr. William H. Stewart, in which he recommends that "in order to make accurate localizations, the roentgen examination should be made fluoroscopically in the operating room, the patient being placed in a position similar to that in which he is placed by the surgeon for the operation. Roentgenologists now have a small Coolidge tube which is immersed in oil in such a way that all of the high tension wires are protected so that danger from shock to the operating room force is eliminated. The fluoroscopy is done by the roentgenologist in the operating room, with the aid of a hooded

the experienced surgeon the desired information regarding the actual extent of the disease. Still in determining whether radical or a more conservative operative interference is indicated, it is of very great value to know beforehand the exact location and extent of the disease.

#### PROPHYLAXIS

1 *Aspiration of Stomach Contents During and After Operation, also During Gastric Lavage*—Careful preparation of the patient for operation, trained anesthetists in attendance at the operating table, and watchfulness *after* the patient has been returned to his bed, combined with proper posture (Sims'), more important still, gradual widening of the field of regional and local anesthesia in our daily operative work, will help to reduce the number of lung affections due to aspiration during and after the operation. Sims' posture in horizontal or in a slight Trendelenburg position will prevent aspiration of mouth secretions and vomited material while the patient is being returned from the operating table to his bed, as well as later, also during gastric lavage.

2 *Aspiration During Nasopharyngeal Operations*—Instrumental evacuation of fluids from the mouth and throat by continuous suction, with proper posture of the patient during tonsillectomy and adenoidectomy, better still, operation performed under local anesthesia whenever possible, with crushing of the blood vessels before division, at least in older children and in adults, will enable the specialist to prevent, or reduce to a minimum, aspiration of infectious material below the glottis in the course of his work.

If the operator prefers general anesthesia—and he may be justified in this because a number of deaths, seemingly directly due to local anesthesia in cases of tonsillectomy, have of late been reported—a trained anesthetist is the principal factor in avoiding lung complications. Certainly, this most important subject of performing tonsillectomies and nasopharyngeal operations under local or general anesthesia is in great need of further unbiased discussion.

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fluoroscope, through which he can clearly see the course of the needle and thus aid the surgeon in locating the abscess cavity. I quite agree with you that one cannot depend on this method alone, and that preliminary localization should be made prior to the fluoroscopy in the operating room at the time of the operation. Difficulty in making accurate preliminary localizations is largely due to the following: (1) neglect on the part of the roentgenologist properly to center the roentgen-ray tube through the diseased area, (2) considerable change in the localization during inspiration and expiration, (3) examination of the patient most frequently in positions which do not correspond to those used by the surgeon on the operating table, (4) relaxation of the patient when fully anesthetized and on the operating table, which has a tendency to change conditions to some extent from those which existed at the time of the preliminary localization."

3 *Aspiration of Infected Water While Swimming*—Lung abscess due to aspiration of infected water is a rare occurrence. However, a few true cases have been observed by the late Dr. Lynah of New York City in two boys who had gone for a swim in the infected waters surrounding Manhattan Island. One of them almost drowned. In every case, the colon bacillus was found in pure culture in the lung abscess.

This observation affords important hints as to how to avoid such occurrences in the future, and how eventually to prevent a full development of the late results of such aspiration. In order to prevent such occurrences absolutely, it is necessary to give New York and other cities similarly situated a proper drainage system conforming to the rules of modern advanced sanitation, and stop draining directly into the rivers surrounding our large cities. That, however, is for the present moment a "pium desiderium."

With regard to forestalling the full development of lung suppuration due to aspiration in general, by means of preventive therapy, it seems to me that experience with the bronchoscope already at hand clearly points to the necessity of a quick, aggressive plan of treatment. Knowing that the late result of any type of an aspirated foreign substance into the lung means almost always suppuration of the lung, the primary duty of the physician and the surgeon is clearly outlined. The foreign substance which has entered the bronchial system, be it solid, semi-solid or liquid, ought to be removed as soon as possible, before it has time to get a firm hold on the lung tissue itself. Judging from the remarkably beneficial result of bronchoscopic suction in an early case of mine, and a few additional similar ones seen by others, I incline to the hope that prompt cleansing of the stem bronchi and their respective divisions, which may clinically mean cleansing also the adjacent lung tissue itself, by means of aspiration in the hands of an expert, irrespective of the presence of high fever and general malaise, will prove a most valuable prophylactic means in avoiding, or at least mitigating, the threatening acute, subacute and chronic lung suppuration in some of these patients.

Who can tell but that perhaps in the future the medical man will join hands with the bronchoscopist, even in the treatment of pneumonia proper, not alone of the aspirating type, when it comes to particularly difficult, long drawn-out cases? How clearly, then, it is the duty of every modern hospital to have on its staff an expert bronchoscopist.

#### TREATMENT

In the beginning of our thoracic work, the indication as to whether and how to proceed could not be correctly established. We were actually groping in the dark. With the personal willingness to help

these patients by operation, and not always knowing which method, conservative or radical, would be best adapted to the case in hand, also trying to help in developing the various operative procedures, I feel today, on looking back, that several patients were operated on to whom it would have been better to refuse operation, and that some patients were submitted to a definite surgical interference in whom another procedure might have given better results

Before glancing over the practical results that have been obtained and observed by me within the last twelve years by the various methods of surgical treatment, specialistic and operative, in acute, subacute and chronic nonspecific lung suppuration, a brief statement appears proper as to how it came about that I have tested "all" the conservative methods of dealing with the disease in question, besides, of course, treating several patients also with resection of the lung

In our experimental work at the Rockefeller Institute, in the years 1908 to 1912, we had found that healthy dogs stood the removal of one or more lobes of the lung very nicely. They were almost entirely well after forty-eight hours, jumping around and barking as if nothing had happened—another proof of Nature's wonderful generosity in endowing the animal (human) system

Of twenty-six dogs thus operated on, twenty-two recovered (84.6 per cent) <sup>2</sup> When testing the contents of the chest, in the place of the removed lung lobe or lobes, the aspirator invariably found air, never fluid, in contrast to the experience of Sauerbruch and Robinson, who always found fluid <sup>3</sup>

I believe, with a perfectly aseptic course of healing after lobectomy in the healthy dog, with separate ligation of the blood vessels that accompany the bronchus, also with crushing, combined with air-tight inversion and suture of the bronchial stump and subsequent immediate complete closure of the chest, air will be found as a rule within the chest in place of the excised lung portion, and not serous fluid <sup>4</sup>

The anatomic proof of how Nature then takes care of the resulting defect was rendered possible through the courtesy of Dr Francis Carter Wood of New York, who was good enough to give us his active assistance in this part of the work. At various intervals after the operation, under general anesthesia, he bled to death the dogs thus operated on, through an incision into the femoral artery, and then injected a 5 per cent aqueous dilution of liquor formaldehydi into the vascular system. Thereupon, the cadaver was frozen and the thorax

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2 Meyer, Willy. *Zentralbl f Chir* **36** 1713 (Dec) 1909

3 Sauerbruch and Robinson. *Deutsch Ztschr f Chir* **102** 542, 1909

4 Heuer, G J, and Dunn, G R. *Bull Johns Hopkins Hosp* **31** 31 (Feb)

cut horizontally with a saw, at different levels. The specimens thus obtained were most instructive. They proved, anatomically, what had long been observed clinically in patients with diseased portions of the lung, namely, that the opposite mate hypertrophies, and, through distention of its parenchyma (compensating emphysema), gradually fills the place of the cavity produced by the excision of the lobe. Some of these specimens were shown at the meeting of the American Surgical Association in Washington, 1912<sup>5</sup>. They are still in my possession.

With this experience in mind, May 12, 1909, we approached rather enthusiastically our first attempt at lobectomy in the human being. The patient, a boy, aged 6 years, with typical localized advanced, evidently congenital, bronchiectasis of the left lower lobe, had been referred to me by the late Dr. Pisek of the Post-Graduate Hospital. With the patient's head and the anesthetist under differential pressure within the positive pressure cabinet—the only type of apparatus for differential pressure then available with the exception of the negative chamber, which had not yet been installed at our hospital—we opened the chest, loosened the adherent lobe and treated the pedicle, bronchus and blood vessels, as we had learned to do in our experimental work. Today, we know that such detailed treatment of the chronically inflamed stump is not advisable in human beings. After the vessels had been ligated, we crushed the bronchus with a powerful clamp, and, just as we were tying it, the anesthetist informed us that the patient had suddenly stopped breathing. Long-continued efforts at resuscitation failed. We were all utterly disappointed and unhappy and tried to explain our experience in various ways: acute dilatation of the right heart, owing to the continuous increased air-pressure in the presence of a heart muscle, weak and diseased from years of septic infection, vagus reflex, etc.

This experience occurred a few weeks before the arrival of Dr. Friedrich, then Professor of Surgery at the University of Marburg, Germany, who had come to America in the spring of 1909, at the invitation of the American Medical Association and the American Surgical Association to attend their annual meetings. When I discussed the boy's death with him, he gave me the following advice: "Do not attempt to excise every chronically suppurating bronchiectatic lung lobe in the human. Lobectomy is still a very serious operation, and thoracic surgery is still a very young child. The many deaths that would most likely result might give thoracic surgery a black eye in the estimation of our medical brethren. Rather go ahead slowly and cautiously, and try conservative methods first." I took his advice, and, in the course of the subsequent years, conscientiously and faithfully

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5 *Tr Am Surg A*, 1910, p 242

tested, step by step, all the various conservative operations advised for the surgical treatment of nonspecific pulmonary suppuration (1) collapse of the lung in the absence of adhesions by means of gas or air (artificial pneumothorax), (2) operative collapse of the lung, in the presence of adhesions between pulmonary and costal pleura, by means of a thoracic incision and intrapleural loosening, with division of these adhesions, and closure of the chest with the lung collapsed, (3) operative collapse of the lung, in the presence of adhesions between pulmonary and costal pleura, by means of extrapleural thoracoplasty (multiple rib resection), (4) ligation of a branch of the pulmonary artery, with or without thoracoplasty, (5) resection of the lung, (6) incision of the lung with drainage, (7) bronchoscopic treatment in the hands of an expert<sup>6</sup>

A bird's eye view of the surgical treatment of suppurative inflammation of the lung permits one to place it parallel with that of suppurative inflammation of the kidney. In acute and chronic pyelitis, we perform cystoscopy and ureteral catheterization with antibacterial irrigation of the renal pelvis, in suppurating pyelonephritis, particularly when due to stone, we employ incision plus drainage, and, in advanced cases, after proper functional tests, nephrectomy. What cystoscopy and ureteral catheterization, inclusive of the use of the operating cystoscope, accomplish in renal surgery, bronchoscopy (peroral endoscopy) does in the early and later treatment of certain suppurative pulmonary processes, nephrotomy corresponding to pneumotomy and nephrectomy to lobectomy.

Let me now briefly survey what I have seen and learned in this class of cases in the last twelve years. I shall do so under the three headings discussed above, namely, lung abscess, bronchiectasis and bronchiectatic lung abscess.

#### A LUNG ABSCESS

These abscesses usually are, as mentioned above, the sequelae of an attack of pneumonia or influenza, possibly some cases are also due to an embolism of an infected thrombus of small caliber and low degree of infection, or to the entrance of bacteria as emboli, by way of the blood stream.

In dealing with the treatment of this disease it must be borne in mind that such a lung abscess may heal spontaneously, as may be seen from the following illustrative case.

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6 I did not try the transposition of the affected lobe according to Garre, nor the subdiaphragmatic transposition of the diseased lower lobe, in combination with, and rendered possible by, artificial paralysis of the diaphragm on the same side by means of phrenicotomy, as proposed by Henschen.

CASE 1—Several years ago, a man with a typical unilocular, suppurative lung disease was seen by me in consultation and admitted to the hospital. General and local treatment (posture expectoration, Priessnitz dressings, good nourishment, etc.) was instituted. Slow improvement followed. A localized cavity, well manifested clinically, persisted. Operation was advised, but not accepted. After several weeks of observation, the patient left the hospital and was lost sight of. Later, by chance (discussion at a medical meeting), definite news regarding the patient's condition was received from his attending physician to the effect that the man had completely recovered without operation.

Similar cases are reported in the literature. The operations for lung abscess which I have performed during the last twelve years are the following:

CASE 2—M. W., a man, aged 41, who had been sick for ten weeks, and who expectorated quantities of pus, had an abscess in the left lower lobe, following pneumonia. The roentgen-ray findings were positive. Aspiration in the eighth intercostal space and paravertebral line detected pus. Operation was performed April 19, 1915, at the Lenox Hill Hospital, under local anesthesia. The eighth and ninth ribs were resected posteriorly, and the intercostal tissues excised. Aspiration in the bed of the ninth rib again detected pus. A large cavity was opened with the Paquelin cautery alongside the needle. Many bronchi communicated with the abscess cavity. Tamponade was followed by cure.

CASE 3—A. L., a man, aged 32, had had influenza four months previously. Since then he had had a cough and purulent intermittent fetid expectoration, of moderate quantity in twenty-four hours. On standing, it formed three layers. The roentgenograph and bronchoscope corroborated the clinical diagnosis of localization in the left lower lobe. The patient was the father of a big family. He consented to operation, but demanded the mildest interference. Jan. 11, 1917, operation was performed under pharyngeal anesthesia. Through an incision in the seventh intercostal space down to the pleura, the lung was seen to move. The pleura was opened, and the lung was perfectly free anteriorly, and, laterally, it was adherent only near the spine, in a larger area, from the level of the incision upward. Pneumotomy was decided on. Aspiration in the paravertebral line, near the posterior wound angle, a needle still entering within the area of incision, revealed pus, from about  $1\frac{1}{2}$  to 2 inches below the surface. The needle was removed and the puncture spot compressed. Resection of the seventh and eighth ribs for their entire length with total excision of the intercostal soft tissues was performed. Air-tight drainage in the ninth intercostal space posteriorly was provided for. Layer sutures of the chest wound were inserted in the anterior three-quarters, care being taken to close the pleural cavity thoroughly. The latter procedure was difficult in front on account of tearing of the tissues. Here iodoform gauze was placed on top of the suture line, the border of a tampon being tucked under the muscle. Repeated aspiration posteriorly then did not draw pus, but the needle dropped into a cavity from which air was easily aspirated. The focus was exposed alongside the needle, the actual cautery dividing the lung perpendicularly downward that is parallel with the spine. Pus and detritus were evacuated. The wound was loosely tamponed, the dressing being held in place by adhesive plaster. Air-tight drainage worked admirably. In the course of the after-treatment, suppurating pleurisy developed with marked febrile symptoms. The varying kinds of pleural discharge could be observed beautifully through the glass tube.



which was interposed in the rubber drainage tube leading from the chest to the syphon below. However, the inflammatory attack was easily overcome by this method of after-treatment. Then followed uninterrupted recovery (Fig 2).

CASE 4—H B, a man, aged 24, the clinical diagnosis of whose case was abscess in the right lower lobe, corroborated by roentgenography, when examined bronchoscopically showed discharge from one branch of the lower lobe only, proving localization of purulent inflammation. Aspiration, with the patient in the sitting posture and in the scapular line, detected pus. Operation was performed, March 8, 1917, at the Montefiore Hospital, under general anesthesia. A curved posterior periscapular incision was made with resection of a good-sized portion of the fourth to the seventh ribs, with the intercostal tissues. Aspiration was successful through a Paquelin incision. Only a small amount of pus was evacuated. Loose tamponade and dressing were applied. The same evening, the pulse was 132, respiration 40, indicating aspiration pneumonia. The first deep dressing was made on the seventh day. The wound was in good condition. The high temperature with rapid pulse continued. March 16, the patient died. Necropsy revealed the principal abscess cavity in the lowest portion of the upper lobe, separated from the operative field by a very thin wall. Multiple lobular pneumonic foci were detected in the left (opposite) lower lobe, evidently the cause of death.

*Epicrisesis*—1 When only a small amount of pus is found on opening a lung abscess, a larger quantity being expected, exploratory puncture should be made from within the lung wound in various directions in the search for neighboring cavities.

2 Local anesthesia should be pushed to the limit, when operating on these patients.

CASE 5—A man, aged 35, had an abscess in the upper portion of the left lower lobe, from no definite cause. He had been sick for five months, coughing pus, at times mixed with blood. Aspiration by a consultant outside the hospital had detected pus in the axillary line. Clinical examination, with stereoscopic roentgenography and bronchoscopy, located the cavity at about the fourth intercostal space in the axillary line. No foreign substance was seen within the bronchial tree. Operation was performed, Oct 22, 1917, at the Lenox Hill Hospital, under local and general anesthesia, later on a general anesthetic being required. The skin incision was made over the fourth rib in the axillary line. Resection of a portion of the fourth and fifth ribs was made, then also of the third rib through the same incision. When excising a piece of the third rib a rent was torn in the pleura above the upper border of the bone. The opening was used for exploration with the finger. The lung was found adherent in the fourth intercostal space, otherwise it was perfectly free. The pleural rent was temporarily compressed with a pad of moist gauze. Aspiration in the fourth intercostal space, within the area of adhesion, detected pus, about 2 inches deep. With the needle and syringe held in place by an assistant, air-tight drainage of the pleural cavity in the ninth intercostal space, posteriorly, was quickly carried out. Closure of the pleural rent by suture proved technically impossible, therefore, the costal pleura was stitched to the surface of the lung. At one place, a gauze tampon was required as the tissues tore. Trusting in the efficacy of the air-tight drainage of the pleural cavity, and also having had a fortunate similar experience (Case 3) in mind, the lung was incised alongside the aspirating needle.

with the cautery, and the abscess emptied and drained. The lung wound was left wide open. The first three days the convalescence was favorable. The temperature was slightly higher than before operation, the pulse was good. On the fourth day, some emphysema of a mild degree appeared around the face, neck and upper extremities. It was nonprogressive. The temperature was low, pulse, full, though above 120. Arrangements were made to change the deep dressing under differential pressure, when the patient suddenly died.

Only wound inspection was permitted. A small amount of turbid fluid was found in the pleural cavity, and some air bubbles in the mediastinum.

*Epicrasis*—1 Too many ribs should not be excised for opening a lung abscess, when the abscess has been definitely located. Resection of one or of two adjacent ribs, here the fourth and fifth, would likely have given the access required and the desirable yielding of the chest wall during cicatrization.

2 A rent in the pleura presents a grave complication. Particular care is required on the part of the surgeon when resecting ribs in the upper portion (from the fourth upward), where this accident is particularly liable to occur on account of the triangular shape of the ribs.

3 In case an accidental pleural rent does occur, which cannot be closed by suture, a two-stage operation is preferable, viz, immediate complete closure of the wound with air-tight drainage of the pleural cavity, incision of the abscess being performed at the second stage.

CASE 6—A woman, aged 26, who had postpneumonic lung suppuration, had been sick for many months. She had high fever, and expectorated 400 cc of sputum in twenty-four hours. The roentgenogram revealed clearly a cavity in the right upper lobe. The patient was admitted to the hospital, Oct 18, 1919. Under careful nursing and hydrotherapeutics, steady general improvement occurred, as well as local improvement, as shown by gradual decrease of sputum and diminution of roentgenographic shadow. But the patient was restless and pleaded for the carrying out of treatment that promised quicker, definite results. November 20, aspiration of the lung anteriorly and posteriorly, was performed in various places, with preparations ready for immediate operation. The result was negative, and operation was advised against. Conservative treatment was continued. There was no further rapid decrease in the cough and amount of sputum. The patient insisted on operation for various personal reasons. The surgeon's better judgment, which favored further temporizing, was overcome by humanitarian sentiments. Operation was performed December 3, with no primary aspiration. On the basis of the roentgenologist's exact measurements as to localization of the pulmonary focus which placed it nearer the back and after thorough preparation by means of regional and local anesthesia, a posterior hook incision was made. The scapula was loosened and pulled aside, the fifth to the seventh ribs inclusive, being resected. The intercostal tissues were excised. The pleural leaves appeared adherent. Repeated aspiration at various levels and in different directions from the exposed area failed to reveal pus, but the syringe barrel filled quickly with air at one place, and the patient expectorated some blood. Remembering the rule that easy aspiration of air into the barrel of a faultlessly working syringe has, more or less, the same value clinically

as aspiration of pus, it was assumed that the abscess cavity had been struck, its contents having been evacuated by posture and voluntary expectoration before operation. Actual cautery division of the lung tissue was accomplished. Suddenly severe hemorrhage occurred, which did not cease when gauze tampons were gently removed after prolonged digital compression. It became necessary to stop the operation, pack the lung wound, and compress it with broad strips of adhesive plaster. After a few days of comparative well-being, a slowly rising temperature, with increased pain and cough, developed. The deep dressing was changed, the wound was perfectly dry, and there were no granulations. Some pus oozed from the lung wound. On the ninth day after operation, the patient died with symptoms of lung edema. Necropsy or wound inspection was not permitted.

*Epicrisis*—1 The surgeon should not submit to the patient's wishes in the face of gradual improvement, in this class of case, which may mean spontaneous cure.

2 If pneumotomy is decided on, one should try to enter the lung from the front or the side, not from behind, even if roentgenography localizes the focus nearer the back than the front or the side. It is evident, and clinical experience proves it, that the larger sized pulmonary vessels are more easily injured by posterior approach.

#### COMMENT

In thoracic operations in general, as well as in the operative treatment of typical lung abscess, I consider it to be of the utmost importance and greatest benefit to the patient, if a "virgin" pleural cavity had been entered during the approach to the focus, accidentally or intentionally, or if a pleural cavity had been opened that presented but a few adhesions, to arrange the further advance in such a way that the thorax will be closed with air-tight drainage at the completion of the operation. Never, to my mind, should a gauze tampon, even if hermetically covered with a rubber dam—the latter's borders then being glued to a cover of sterile zinc ointment, spread over the skin—be left in the angle of a pleural incision or a pleural rent, if the latter tears on suture and cannot be securely closed otherwise. It seems advisable, then, to decide on a two-stage operation and close the incision completely, employing air-tight drainage of the chest, after the hand palpating within the pleural cavity has detected the situation of lung adhesion, which almost invariably corresponds to the suppurating focus beneath. A superficial cross mark with the knife should mark this important spot on the skin. This is the place where the aspirating needle must enter when the first incision has firmly healed.

If conditions permit incision and drainage of the abscess at the same sitting, it naturally affords an advantage for the patient (Case 3). However, these have to be looked upon as representing particularly

fortunate occurrences I feel that the patient in Case 5 would have had a better chance for recovery had I performed the operation in two stages. He died, I think, not as a result of infection caused by incision and drainage of the abscess at the same sitting, but of infection caused by the incomplete closure of the thoracic wound, producing an incomplete postoperative lung collapse, a "sucking wound," with its ever great invitation to general sepsis.

If for any reason air-tight drainage of the pleural cavity appears impossible, it would be taking chances to close the thorax and leave the patient to himself. Under such conditions, the pleural wound that cannot be closed should, to my mind, be left open, completely or partially, with rubber tube drainage, as applied in other parts of the body, and the patient promptly placed under differential pressure after-treatment. That is to say, if a positive pressure cabinet or a negative chamber is available, one of these should be employed, preferably the latter, if not available, then any other device which will prevent the postoperative lung collapse. This treatment should be continued until the lung has become adherent to the chest wall, and the dangers of the occurrence of the postoperative pneumothorax have passed. This will be in from twenty-four to thirty hours, on an average.

There is no doubt that the incision of the lung is attended with many risks, the principal ones being (1) opening of the free pleural cavity, (2) hemorrhage.

The annoying and sometimes dangerous complication of opening a free pleural cavity during incision of a lung abscess can be avoided, or its frequency at least be reduced by (a) a greater precision in localizing the diseased focus within the chest, on the part of the roentgenologist, (b) resection of a sufficient number and a sufficient length of ribs to permit reaching the place where the lung has become adherent.

As mentioned above, I trust that the further development of the method of roentgenography with the help of gas insufflation into the body cavities—in these cases the creation of an artificial pneumothorax for no other purpose than to find and localize the pleural adhesion or adhesions of the lung—will in the future frequently enable the surgeon to obviate the necessity of an exploration of the pleural cavity with the knife for the sake of precise localization of such adhesions. What we need is more clearly to define the exact place where adhesions between the two pleural leaves have formed, whether anteriorly, laterally or posteriorly, also at what level of the thoracic cavity, and thus render the same precision for the chest that pneumoperitoneum has afforded in diagnosing intra-abdominal adhesions.

If such diagnosis of the situation and extent of pleural adhesions could be definitely established, preliminary aspiration of the affected lobe one or two days previous to the operation, so greatly desirable

in conservative lung surgery, yet so much and justly feared, will have lost its dangers. It certainly is a tremendous advantage, and greatly relieves the surgeon's mind, if all the important diagnostic questions have been definitely settled before he starts to operate.

The extent of rib resection to afford greater exposure of the lung surface, covered by parietal pleura plus endothoracic fascia, must, of course, be determined by clinical findings. Observation of the mobility of the lung during respiration through these two, normally very thin, membranes helps in recognizing the best place to enter the lung, and the color of the lung surface also represents a reliable guide. When the lung is diseased, the normal yellowish-pink appearance, revealed as it shines through the overlying membranes, gives way to a bluish-black discoloration. This is the place where the chronically inflamed lung usually has become attached to the chest wall.

#### B BRONCHIECTASIS

The characteristics of this condition are multiple lung suppuration of one or more lobes, of long duration, honeycomb appearance of the affected portion of the lung on cross-section, due to the presence of many scattered suppurating foci. Some of these show, in advanced and badly infected instances, calcified walls and strictured bronchial entrances, representing typical cesspools that harbor a fauna of partially anaerobic bacteria, which are principally responsible for the foul odor of the patient's sputum, the presence of easily bleeding granulations or irregular ulcerations, at or near the neck of these cavities, the former causing slight intermittent hemoptysis, the latter sometimes severe, eventually fatal, hemorrhages. A diffuse, putrid bronchitis is frequently coexisting.

This particular type of suppurating lung disease is, in the great majority of cases, probably dependent on a congenital malformation or arrest of development. Many authors believe that it is also due to the sequelae of the aspiration of a foreign body, or to the obliteration of the pleural cavity subsequent to an empyema, that means, to a uniform and broad adhesion between the visceral and parietal pleura of the affected portion of the lung.

An aspirated foreign body, solid or semisolid, will interfere with the free access and exit of air to and from a certain part of the lung, will obstruct, and being nonaseptic, will carry into the bronchial tree, with respiration, a continuously present, infecting and reinfecting agent. Such infection naturally produces inflammation and finally suppuration. However, it is hard to conceive, always thinking and speaking from the standpoint of the clinician, how aspiration of any sort could produce the typical classical picture of lung suppuration, which patho-

logically is termed bronchiectasis. Whether a fluffy foreign body arrested within the lumen of a bronchus, for example, a bit of aspirated timothy grass which I observed as a causal factor in a case of diffuse lobe suppuration in a young boy, or whether a benign intrabronchial tumor will ever produce typical bronchiectasis, remains to be seen. Personally, I doubt it.

The patient suffers from a persistent cough, usually with a large daily quantity of more or less fetid sputum, which is often streaked with blood, but which does not show elastic fibers. It presents three layers on standing. There are clubbed fingers and toes, often irregular persistent fever, and metastatic joint affections may set in. The clinical picture is that of tuberculous lung affection, but tubercle bacilli in the sputum are always missing. The lung apexes are not involved, but other parts of the lung, principally the lower lobes, are affected, more so on the left than on the right side.

Clinical examination is often almost negative, particularly when the patient has just expectorated. The roentgenograms reveal diffuse opacity, sometimes with small cavities, the findings are often unsatisfactory. Bronchoscopy in the diagnosis more definitely defines the involvement.

*I Medicinal and Hygienic Therapy*—This is without effect.

*II Specialistic (Endobronchial) Treatment*—It stands to reason, and it has been my observation, that intrabronchial local therapy, viz., suction with antiseptic applications and irrigations of the bronchial tree, can but slightly improve this type of lung suppuration. It should be tried if operative advance appears absolutely contraindicated. Its effect will at best, if combined with posture expectoration, be subjective. Though rarely if ever reducing the amount of the sputum it will reduce its foul odor, thus making the patient more comfortable. Still, there is no reason why bronchoscopists should not continue their investigations in this class of lung suppuration if the patients should be considered by the surgeon to represent too great a risk, or if they or their relatives should refuse radical operation, that means lobectomy.

*III Conservative Operative Treatment*—It should be emphasized here once more that in gathering these personal experiences in the conservative operative treatment of subacute and chronic lung suppuration in the course of years, the differential diagnosis as to the various classes as outlined above was not made during the first years. Every case of advanced lung suppuration that did not seem to be a locally defined abscess was termed—and is still termed here, in reporting the brief histories of patients who in the beginning of our thoracic work came under treatment—bronchiectasis.

Of the conservative methods enumerated above the first three, viz., simple collapse of the affected lung by means of artificial pneumo-

thorax, intrapleural freeing of the lung from its adhesions plus artificial collapse, and extrapleural thoracoplasty do not impress me as promising satisfactory results

1 *Simple collapse of the affected lung, in the absence of broad adhesions, accomplished by establishing artificial pneumothorax*

CASE 7—A girl, aged 22, who was much reduced, with bronchiectasis of the right middle and lower lobe, had been sick for four years. In the spring of 1915, regular intermittent nitrogen insufflation was employed, covering a period of several weeks, through the courtesy of the late Dr Whidden. No improvement resulted.

Other authors have tested the effect of artificial collapse of the lung in acute and chronic suppurating lung disease longer and oftener. Volhard succeeded in keeping the affected bronchiectatic lung, in an advanced case, collapsed for many months, with symptoms improved. When the patient and physician had become tired of this treatment, and it had been discontinued, allowing the lung to distend gradually, the original trouble reappeared in its former severity.

Tewksbury<sup>7</sup> of Washington wrote two very interesting articles on early artificial collapse in beginning lung suppuration after operations on the nose or throat, reporting ten cases with rather phenomenal clinical improvement, six cures and two deaths. The method promised to become the treatment of choice in this class of cases. Lately, Rich<sup>8</sup> has again recommended artificial collapse for the early treatment of lung suppuration. He reports ten cases: one following a pelvic operation, one following a simple cold, one following tonsillectomy under ether anesthesia, two following bronchopneumonia, four following the influenza bronchopneumonia syndrome. In several of these cases, the roentgen-ray findings made it certain that interlobar empyema preceded the abscess formation. It will be important and interesting to have the final results of these cases published after a number of years. It is hard to conceive how that method can compete with early bronchoscopic suction in suppurations due to aspiration.

2 *Operative intrapleural freeing of the lung from its adhesions and closing the chest, with the lung in a visibly complete collapsed condition, followed by subsequent gas insufflations*. We tried this method in Case 7.

7 Tewksbury, W. D. Acute Pulmonary Abscess Treated with Artificial Pneumothorax, J. A. M. A. **68** 770 (March 10) 1917, Treatment of Nontuberculous Lung Abscess with Pneumothorax, *ibid* **70** 293 (Feb. 2) 1918.

8 Rich, H. M. Acute Lung Abscess Treated by Therapeutic Pneumothorax. Am. J. M. Sc. **164** 428 (Sept.) 1922.

May 24, 1915, thoracotomy was performed in the negative chamber, superficial chloroform anesthesia being employed. The incision was made in the sixth intercostal space. The lung was nowhere adherent to the chest wall. The middle and lower lobes were visibly diseased, and partially atelectatic. Firm adhesions to the pericardium and diaphragm, also in the complementary space posteriorly, were loosened bluntly and divided between the ligatures. The lung was allowed to collapse, and the chest closed air-tight. The patient stood the operation nicely, and was wide awake when leaving the table. The recovery from the operation was uneventful. Gas insufflation was soon continued in order to keep the lung totally collapsed. There was no marked improvement in clinical symptoms. Relatives insisted on the patient's discharge from the hospital, and she died at home several months later.

*Comment*—The latter method of combating subacute and chronic lung suppuration has never appealed to me, nor has its use in tuberculous patients. If sufficient adhesions are present to prevent lung collapse by gas insufflation, and a conservative operative method is desired, collapse of the lung and the chest wall, with the help of multiple rib resection, appears more rational and logical. With all due care, the surgeon will often not be able to avoid tearing the lung parenchyma, thus inviting pleural infection.

How far thoracoscopy with division of adhesions, localized by direct inspection—the method inaugurated by Jacobaeus of Stockholm—will assist in handling such cases, the future must show.

3 *Extrapleural thoracoplasty, resection of from nine to ten ribs, without preliminary ligation of the branch of the pulmonary artery in cases in which adhesions between the two pleural leaves have rendered collapse by nitrogen or an insufflation impossible*

CASE 8—A woman, aged 22, with bronchiectasis of the right lung, came under treatment at a time before the bronchoscopist had become the thoracic surgeon's faithful ally. Under local anesthesia and, later on, a few whiffs of anesthol, the patient stood very nicely the resection of the ten upper ribs (inclusive of the first) in two sittings, Jan 23 and March 8, 1915. However, she developed an empyema on the same side during the after-treatment of the second stage. With this drained, she was well at last and up and about, though little improved so far as the amount of sputum and other symptoms were concerned, when an acute suppurative meningitis developed, of which she died.

It is worth remembering that about one fourth of the patients afflicted with bronchiectatic lung suppuration are stricken by suppurative meningitis in the course of the disease (Tuffier).

CASE 9—A woman aged 45 was extremely emaciated as a result of post-pneumonic suppurative affection. The sputum amounted to from 5 to 600 c c. Daily expectoration in the pronounced knee-elbow posture brought great subjective relief. Under local anesthesia and very superficial anesthol general anesthesia permitting conversing with the patient during the entire operation, resection of the tenth to the first rib, inclusive was performed at one sitting.



Feb 25, 1915 The patient stood the operation well, but continued to expectorate the same amount of sputum as before operation. She lived several weeks and then died of exhaustion. At necropsy a single old abscess cavity was found in the center of the upper lobe, and a second abscess, with the same characteristics, in the center of the lower lobe, presenting a picture of multiple typical lung abscess.

CASE 10—A young man, aged 21, with bronchiectatic affection of the lower right lobe, whose family was opposed to any major intrathoracic operation, made an uneventful recovery after extrapleural thoracoplasty, with resection of the sixth to the tenth rib, inclusive, under local anesthesia, in December, 1919. Two years after operation, he reported no reduction in the quantity of sputum.

4 *Ligation of a branch of the pulmonary artery, with or without subsequent extrapleural thoracoplasty.* Sauerbruch and Bruns, in their experiments on animals, found that ligation of the branch of the pulmonary artery supplying the area of operation, which means eliminating the function of the lobe, produced a pronounced formation of connective tissue in that part of the lung, the latter becoming firmly adherent to the chest wall.

This operation was tested by Sauerbruch on fourteen patients, all of whom recovered from the operation. Twelve times it was combined with subsequent multiple rib resection. Great improvement, approaching a cure, was seen in two patients, two were very much improved, less pronounced improvement was seen in one, one remained unchanged, one, not improved, died of meningitis one and a half years after operation, the remaining seven, not improved, were subjected to lobectomy.<sup>9</sup>

Davies of London performed the operation once on a young man, aged 17, with great improvement of the disease. The left lower lobe was affected.<sup>10</sup>

My personal observation includes three cases.

CASE 11—A young Italian, aged 17, who had been sick for five years, lately under sanatorium treatment expectorated large quantities of foul sputum. Tubercle bacilli were never found. The right middle and lower lobes were affected. Bronchoscopic corroboration was not practiced at that time. April 4, 1912, the lower branch of the pulmonary artery was ligated in the negative chamber. Operation was begun under the novocain plus epinephrin anesthesia. An intercostal incision was made in the fifth space, down to the pleura. The lung was seen to move. The pleura was opened and a rib spreader put in place. Then superficial nitrous oxid and oxygen anesthesia was employed on account of continuous coughing and pressure. The lower portion of the lung, of dark brown appearance, infiltrated on palpation. There were many adhesions to the diaphragm, mediastinal tissues and at the apex. After blunt loosening and division of these, the lung could be brought forward. The interlobar space was obliterated, just marked by a fine line. An attempt at separation tore the

9 Sauerbruch, F. *Chirurgie der Brustorgane*, Ed 2, 1 587, 1920.

10 Davies, H. M. *Surgery of the Lung and Pleura*, New York, Paul B. Hoeber, 1920, pp 219-221.

lung Therefore, the lung was pushed outward, and held by an assistant, and the stem of the bronchus was palpated and exposed The pulsating vessel on its upper surface was ligated with silk, as was also a second larger branch above, seemingly running to the middle lobe Toilet of the pleural cavity was performed, complete layer closure of the chest without drainage was accomplished Recovery was uneventful A pleural effusion proved, on tapping, the presence of clear fluid which was sterile Complete thoracoplasty of the second to the tenth ribs, inclusive, also of the rib cartilages, was performed under local and regional anesthesia, in three steps, four and one-half, six and eight weeks after the first operation The patient was discharged improved, as regards quantity of sputum He was presented to the New York Surgical Society One year later, during the summer, he was admitted to the Post-Graduate Hospital with symptoms of suppurative meningitis, and died Necropsy was not performed

CASE 12—A young man, aged 17, greatly underdeveloped, had expectorated copious massive foul sputum for years He had been in a sanatorium many months, but no tubercle bacilli had been demonstrated The left lower lobe was involved Operation was performed, April 25, 1912, in the negative chamber It was begun with local and regional anesthesia, later nitrous oxide and oxygen being employed A seventh intercostal incision was made The portion of the lung that appeared was not adherent to the lateral chest wall, but at other places it was The lower lobe was densely infiltrated on palpation, and not loosened The interlobar space could be entered nicely, but it was closed so tightly by adhesions, farther down toward the main bronchus, that advance was not pressed Again, the lung was held outward by the first assistant and the stem-bronchus approached as in Case 11 When the adhesions were gently pushed away with a stick sponge, the upper branch of the pulmonary artery appeared After further careful dissection, the lower branch also soon came into view A swollen lymphatic gland rested in the angle of the fork The lower branch was ligated Complete closure of the chest was accomplished without drainage The patient stood the operation nicely Two days later, some subcutaneous emphysema appeared in the lower half of the abdominal wall, on the left side A turbid serosanguineous effusion into the left pleural cavity, found on tapping, required partial reopening of the wound After that, the recovery was slow but satisfactory One year later, the patient was much improved There was a great increase in weight, expectoration was reduced to 100 cc in twenty-four hours May 15, 1913, a thoracoplasty was performed, under local and regional anesthesia, the sixth to the tenth ribs, inclusive, being resected in their entire length Recovery resulted Two years later there was a decided improvement, but the patient was not cured Further surgical interference was refused by the family The patient was lost sight of

CASE 13—A man, aged 22, an architect, very intelligent, had bronchiectasis of the right lung involving the lower lobe There were few clinical signs, very foul copious sputum, from 3 to 400 cc in twenty-four hours, often tinged with blood No bronchoscopic corroboration was possible The roentgen ray revealed dilatation of the right bronchus and diffuse infiltration of the lower lobe Feb 25, 1913, ligation of the pulmonary artery of the right lower lobe was performed, in the negative chamber, under regional and local anesthesia, through a fourth intercostal incision The lung was found not adherent Placing of the rib spreader gave the patient a "severe pressure sensation" On account of reflexes when the lung was handled a few whiffs of anesthol were given, not more than 5 cc being used in all Then operation was continued under local anesthesia as before The pericardium was tightly adherent to the lung, cardiolysis was performed There was a well marked interlobar space, adhesions within were gradually

loosened until the main bronchus was reached. During this manipulation, the lung was slightly injured. When the patient pressed, some mucopus escaped from the small sized bronchial opening. The vagus branch was recognized, repeated application of absorbent cotton, thoroughly soaked in 1 per cent novocain and epinephrin solution, were made on the bronchial root. Hardly any reflexes were noticed afterward. The artery to the "north" of the bronchus was carefully loosened and ligated with silk. In view of the possible infection of the pleura by way of the exit of bronchial secretion, free drainage of the pleural cavity was established through an incision posteriorly in the ninth space. The chest incision was closed. The patient was retained under differential pressure for twenty hours, when he was in good condition. Two days later, some subcutaneous emphysema appeared over the lower abdomen, the right half of the scrotum and the left side of the neck, with increase of temperature. The posterior angle of the wound was opened. Some serosanguineous and clear fluid escaped. He was soon out of bed. Recovery followed. Three years later, the patient wrote from Georgia that cough with expectoration often occurred only once a day. Sputum amounted to 15 cc in twenty-four hours. His general health was perfect, and he was at work in out-of-door construction. In the spring of 1922 he was still living in the South and married. His general condition was excellent. There was no cough. Expectoration had ceased completely. He considered himself cured.

*Epicrisis*—It sets one to thinking when one sees a patient, who was thus afflicted, so much improved after this operation that in a suitable climate he could reenter business and become a useful self-supporting citizen, and that such result was obtained even without a subsequent thoracoplasty, which had been proposed but was not accepted by the patient.

*Comment*—It is important to remember that the pulmonary artery lies "north" of the bronchus, toward the patient's head. The operation may be technically difficult on account of firm adhesions between the lobe surfaces themselves, the affected one forming a unit with its neighbor. On separating these adhesions, no matter how gently done, the lung tissue is easily torn, an occurrence which naturally at once carries an infectious element into the otherwise aseptic operation. Such occurrence requires categorically air-tight drainage, a procedure which I employ after any and every intrathoracic operation.

5 *Resection of the lung* In one instance, I tried this operation before resorting to lobectomy, the patient having requested me to take as little chance as possible in the course of the operation.

CASE 14—E. W., a widow, aged 53, with no children, with bronchiectasis of the left lower lobe, had been repeatedly operated on at another hospital. Her present trouble commenced in January, 1910, and was evidently consecutive to an intrapulmonary abscess following pneumonia with empyema on the left side. A fistula persisted. Injected bismuth paste was coughed out. Multiple rib resection brought no improvement. On admission to Lenox Hill Hospital, examination revealed a long scar in the chest wall, at about its middle, posteriorly, it afforded wide entrance into a lung cavity showing many open

bronchi. The patient was well educated and determined to secure relief. May 8, 1914, under general anesthesia in the abdominal posture, the scar was circumscribed, with reresection of the tenth to the sixth rib, an additional resection for some length of the fifth rib, which had not been touched at the former operation, was performed. The scapula was held aside, and advance arranged in such a way that the opening into the lung remained in the center of the operative field. The costal pleura was divided below the fistula, exposing the lung, which was gradually loosened entirely from the complementary space where it was tightly adherent. At last the thickened pleura with the overlying tissues was excised. Then the pulmonary cavity was laid wide open with the cautery. It was seen that there were at least ten to fifteen various openings of the bronchial tree. In view of the fact that the lower lobe was completely adherent to the upper and could have been separated from it only by a free division, necessitating special suture of the upper lobe, as well as in view of the patient's general condition and age, it was deemed wiser to resect the lower lobe than to extirpate both. Two curved clamps, as used in gastro-enterostomy, covered with rubber, were placed on either side of the open cavity converging toward the hilum, and then the diseased portion was excised in the shape of a wedge with the knife, leaving a sufficient amount of tissue in front of each clamp. Careful disinfection (pure phenol and alcohol) and ligation of the open bronchi with the accompanying blood vessels were accomplished. On removing the clamps, only a few additional ligatures were required. Then an inverting suture of each remnant of the lobe with chromicized gut, starting at the periphery, was inserted. Finally two rounded taillike portions remained, which were sutured on each other. Tamponade and drainage were established. The patient stood the operation nicely. Recovery was good. Three weeks later, when the patient was required to press, with compressed nostrils and mouth closed, bubbles of air could be heard escaping from the lung, one larger sized bronchial fistula developed. Prolonged after-treatment exhausted all methods employed for closing this type of fistula. The fistula finally did close, but then there was more expectoration, from 50 to 100 cc in twenty-four hours, with the patient rather sick. The lung was reopened, causing a copious purulent discharge. The good general condition returned, proving that it can be maintained with free pulmonary drainage only. The patient was referred to a home for tuberculous patients, the only institution willing to admit her.

*Comment* —Although I have only this one personal experience with lung resection at my disposal, I, nevertheless, after mature consideration of the subject, think that I am justified in saying that this operation has no place in the operative treatment of chronic lung suppuration. It would certainly be mere luck if the excised wedge of the lung should radically remove the diseased area. The operation, therefore, will likely improve only the pathologic condition. Of course, if a patient or his relatives will not accept the risk of lung excision, and it can be arranged to place the expected fistula within the immediate view and reach of the patient, the removal of the greater portion of a suppurating lung lobe might, after all, receive a place among the operations that are in use at present for the surgical treatment of chronic pulmonary suppuration on more conservative lines.

## 6 Incision and drainage

CASE 15—A man, aged 24, four months before had had his adenoids and tonsils removed. Shortly afterward, beginning lung suppuration developed. Later, high fever with rapid pulse developed, together with continuous cough and foul sputum in great quantities (500 to 600 c.c. in twenty-four hours). The roentgen rays added little to the accuracy of the diagnosis. Bronchoscopy at that time was not yet raised to its present position of imperative diagnostic addenda. The patient entered Lenox Hill Hospital, Nov. 2, 1911. Aspiration of the lung in various places was performed. In the seventh intercostal space near the angle of the scapula where some bronchial expiration was noticed, pus was found about  $2\frac{1}{2}$  inches (6.7 cm.) below the surface. Operation was performed November 6, under local anesthesia. The seventh rib was resected, aspiration was repeated and positive. The lung was opened with the electric cautery. An irregular cavity was entered, the size at least of a small apple. On dividing the lung, the free pleural cavity was accidentally opened toward the front. No collapse of the lung occurred evidently owing to its being attached to the costal pleura in various places. A drain was placed in the pleural cavity with gauze packing of the abscess. Gradual closure of the large wound occurred by granulation. A drain was left in place permanently to produce persistent drainage to the surface. Frequent paroxysmal coughs occurred. The quantity of sputum was greatly diminishing. The patient was discharged, December 20. A few weeks later, while the family was preparing to move to the country, the patient was suddenly stricken with acute suppurative meningitis, to which he succumbed within six days.

*Epitaxis*—Today, a patient of this type would, in my hands, first be transferred to the bronchoscopic clinic for intermittent prolonged treatment before I would resort to operation.

CASE 16—A girl, aged 19, who had been sick for sixteen years, subsequent to pneumonia (?) expectorated extremely fetid, massive sputum with cough. She had to leave her place of business and was confined to a room by herself, later being isolated at the Montefiore Hospital for seven months. The clinical symptoms were not clearly marked. There were few râles on the left side and some dulness near the spine. The roentgen rays corroborated left side infection. On aspiration below the angle of the left scapula air and pus, in a small quantity, were withdrawn. Jan. 21, 1914, operation was performed at Montefiore Hospital, in two stages. Regional and local novocain and epinephrin anesthesia was used. Resection of the seventh and eighth ribs in the posterior axillary line with excision of intercostal soft tissues was performed. Aspiration in the bed of the seventh rib was again positive for pus. On disengaging the syringe from the needle, pus spurted from its hub synchronous with inspiration. On cauterizing alongside the needle with a Paquelin cautery a free pleural cavity was entered, but acute pneumothorax did not ensue, evidently on account of adhesions in other places. The lower lobe of the lung was much solidified. The operation was discontinued and the needle withdrawn from the lung. Tube drainage plus gauze tamponade of the free pleural cavity was established. The lung was stitched to the costal pleura in order to have sufficient space for opening at the second stage. Three days later, the first dressing was changed, the pleural tampon being left undisturbed. Aspiration of the lung was again positive. The cavity, opened with the active cautery, admitted easily one half of the fore-

finger. On pushing the needle in another direction from within the lung wound, a second cavity was entered and opened with the cautery. The two were purposely not transformed into one, as a serious hemorrhage might have set in. Separate tamponade was performed. Undisturbed convalescence ensued. The free ventilation of the lung cavities did away quickly with the foul odor of the sputum. After a few weeks, the patient was transferred to the ward, to her great delight, after the long isolation. She was discharged after six weeks. The advice to retain the drain as long as possible was not heeded, the wound being dressed by the family physician out of town. When the drain dropped out accidentally it was not replaced. The patient returned to business, and was last seen in October, 1920. There was occasional cough with scant expectoration, expiratory air had a slightly sweetish odor. She was at work, and hers should be considered an improved case.

*Comment*—Mere incision plus drainage of one or two of the many cavities within a typical bronchiectatic lung cannot possibly bring real help in these cases, for obvious reasons. Such drainage will direct the secretion of only a small part of the involved area to the surface. With the closing of the incision, the original suppuration continues unabated. Besides, suppurative meningitis is a fearful menace in 25 per cent and more, of these cases.

"Action," frequently "daring action," is necessary. That means

#### IV. RADICAL OPERATIVE TREATMENT

Excision of the diseased portion of the lung is here, therefore, absolutely and clearly indicated, if the patient or his relatives are willing to take the risk for the sake of the possibility of a complete cure.

Before discussing the third subdivision, the bronchiectatic lung abscess, I shall say a few words regarding my personal experience with lung excision, as well as with the treatment of lung suppuration due to specific infection (tuberculosis and syphilis), and give a brief resume of experience, gathered by others, in suppuration due to the presence of a benign intrabronchial tumor and a personal observation of suppurating cancer of the lung.

A few cases of lung suppuration, hard to classify, that have come to operation at my hands, will be added, in order to make this personal survey complete.

*Lung Excision*—In four cases the operation remained an attempt that failed, twice, only the first part of the planned two-stage excision was performed, an intercurrent pneumonia frustrating the second. In one case, the entire right lung was successfully excised, and surgical conditions remained favorable after the operation, but the patient developed a most fulminant pneumonia of which he died the night following the operation.

Briefly and chronologically reported, the cases are as follows

CASE 17—A boy, aged 6 years, was operated on, May 12, 1909 (reported above), for congenital, advanced bronchiectasis of the left lower lobe. General anesthesia was used, with the patient's head in the positive pressure cabinet. He died suddenly when the bronchus was being tied, after the accompanying blood vessels had been ligated. Necropsy was not performed.

CASE 18—This was the case of resection of the lung, reported before (see above). A W, woman, aged 54, was unhappy in the home for tuberculous patients, and urged operation. She could have continued to live for some time in the present condition with some attendance, but she was dependent on others as the wound was in the back. Personal reasons were accepted as the real indication for operation, performed, Dec 22, 1915. Local plus regional anesthesia was used, later on, general anesthesia, with anesthol and oxygen. Circumcision of the sinus quickly exposed and gradually freed the lung. A rent in the pericardium, which contained some serous fluid, was sutured. Additional division and partial resection of four more ribs were required to expose the organ fully. As mentioned before both lobes formed a unit. The upper seemed to be as much diseased as the lower was before resection, pus flowing out in abundance at a place which had been superficially torn on loosening the adhesions. There were firm attachments also at the apex. They could be divided between the ligatures so that at last a good pedicle was formed, the stem bronchus being reached. The pneumogastric nerve was pushed off and plainly visible and might have been cocainized without difficulty. Having some little time before successfully performed extrapericardial ligation of the left pulmonary artery for total excision of the lung in experimental work, and being aware that in the upper lobe branch a good deal of granulation had been seen by the bronchoscopist, primary division of the bronchus with local treatment of the bronchial mucosa appeared at that time more desirable than primary tying with a mass ligature. So it was decided to ligate the left main trunk of the pulmonary artery separately first. The latter's course was easily visible, and it was approached at the root of the bronchus where the thin sheath that covers it was divided. With the curved tip of the left forefinger supporting the vessel from beneath, a large Deschamp's needle was made to surround it from the front, most gently. Suddenly, a fearful hemorrhage occurred from the posterior aspect of the artery. Evidently, the Deschamp's needle had perforated the vessel in spite of the gentle handling, there having been no resistance whatever offered from the latter's wall. The blunt needle had passed through it as easily as if it were penetrating jelly or soft butter. Compression with gauze was applied, and an elastic ligature quickly thrown around the base of the pedicle, which, however, on testing, was found not to embrace the injured place of the vessel. While the artery was being clamped, the patient died, probably as a result of aspiration of air into the circulation, and also surely from the sudden great loss of blood.

*Epicrasis*—Should it be thought best in any given operation to ligate the main trunk of the pulmonary artery, only very blunt instruments should be used for separation, e g., a closed blunt, broad Cooper's scissors or Kocher's goiter probe ("Kropf-Sonde"), or, still better, the tips of the two forefingers of the surgeon. Any half-pointed, though blunt, instrument should not be used on account of the extreme softness of the vessel's wall.

CASE 19—A woman, aged 35, with suppuration of the right upper lobe, was operated on in October, 1916, excision being decided on without careful weighing of the indication for incision or excision. Pharyngeal anesthesia in the negative chamber was employed, the latter being used should differential pressure be required. After rib resection, loosening of the totally adherent lobe started, when a remarkable, multiple arterial hemorrhage set in, not unlike the spray from a garden sprinkler under pressure. It probably was due to having entered a wrong point of cleavage, stripping off the two firmly united pleural leaves plus the intrathoracic fascia from the chest wall. Operation was temporarily stopped. The patient recuperated after intravenous infusion. The work was continued, all three lobes formed a unit. While trying to separate the lower lobe from the middle and upper, increasing collapse occurred on the table and the patient died. Necropsy revealed a central single abscess in the upper lobe.

*Epicrisis*—More detailed roentgen-ray localization and incision with drainage might have saved the patient. Since that time the surgeon's proficiency in making a more refined diagnosis has been much increased. We have also learned to demand establishment of a stricter indication for the type of operation to be carried out on recognized pathologic facts in the given case.

CASE 20—A man, aged 53, in whom the entire left lung was involved in a suppurative postpneumonic process, the bronchoscope proving the right lung free, was operated on April 16, 1917, with intratracheal insufflation, Torek's incision in the eighth intercostal space being made. Four ribs were divided upward. The lung, which was totally adherent, was loosened with difficulty, a few superficial tears occurring. The collapsed lobes were surrounded with gauze tampons, according to Robinson's advice. The thoracic wound was then closed with air-tight drainage. An interesting result of the latter was that 250 cc of secretion drained into the bottle in the first twenty-four hours, 700 in the second, 600 in the third, and 400 in the fourth. On the third day after operation, the patient complained of difficulty in expectoration and developed clinical signs of increasing inflammation, likely pneumonia, on the collapsed side, to the sequelae of which he succumbed on the fourth day after operation. Wound inspection revealed no aspiration process on the opposite side.

*Epicrisis*—A one-stage operation removing the entire left lung might have offered a better chance of recovery.

CASE 21—A woman, aged 23, was suffering from suppuration of the right upper lobe subsequent to tonsillectomy. Other parts of the lungs were not involved, as proved by bronchoscopy. She was a trained nurse, utterly unhappy, unable to sustain herself financially and considered herself a burden to her family. The case demanded radical help. Operation was performed, Nov. 10, 1916, with intrapharyngeal insufflation. Torek's incision was made in the seventh intercostal space. The lung was without adhesions, except in the upper lobe, which was particularly broadly adherent at the apex. These were freed by double ligatures and division between them. The base of the pedicle of the upper lobe could be surrounded by the surgeon's forefingers. It was rather massy. The upper and lower lobes formed a firm unit with the middle. An



attempt at separation was only partially successful between the middle and lower lobes. While trying to form a pedicle from the periphery toward the center, after having placed compressing clamps and ligating the tissues with the help of chain sutures, severe hemorrhage with sudden death occurred, probably due to aspiration. A postmortem incision of the upper lobe revealed a central abscess, the size of a small walnut, as in Case 19.

*Epitaxis*—The primary tying of the pedicle, though it was very broad, with a piece of tape or an elastic ligature, before starting to separate the lung tissue from the periphery toward the center, in forcing lobectomy, or, from the start, after refinement of the diagnosis, employing a more conservative program, namely, pneumotomy plus drainage after successful localization of the cavity, might have saved this patient's life.

In the light of present knowledge, bronchoscopic treatment was indicated as the first step in aggressive therapy.

CASE 22—In a boy, aged 5½ years, with copious purulent expectoration resulting from bronchiectasis involving the entire right lung, repeated aspiration by means of the bronchoscope (Dr. Lynch) brought no improvement. Operation was performed, April 26, 1920, with intrapharyngeal insufflation. An attack of cyanosis with respiratory syncope occurred in the course of the operation. Torek's incision was used, affording perfect exposure. Multiple broad firm adhesions, doubly ligated and cut, obtained good isolation of the broad pedicle. Primary clamping in a line parallel with the spine, amputation of the entire lung, careful hemostasis by surrounding the pedicle in front of the clamps with a large round needle and chromicized catgut in sections, careful loosening of the clamps, no hemorrhage, and air-tight drainage in the ninth intercostal space were accomplished. The patient left the operating table in good condition. In the evening, the pulse was good, respiration, somewhat accelerated, he was cheerful and took fluid. During the night, the temperature suddenly rose to 107 F, with corresponding acceleration of pulse, which did not respond to stimulation. He died at 2:30 a. m., ten hours after operation. Partial necropsy revealed edema of the left (remaining) lung (acute fulminant pneumonia?), no evidence of aspiration. Perhaps the cyanotic attack in the course of operation ushered in the severe inflammatory attack.

Pathologic diagnosis of the specimen was lymphosarcoma of the lung, bronchiectasis, no metastases.

CASE 23—A youth, aged 17, had had voluminous purulent sputum for years without fetid odor. No aspiration of any kind had occurred. There was no history of pneumonia. Evidently the case was congenital bronchiectasis of the left lower lobe. This was corroborated by roentgenography and bronchoscopy. Resection of the lobe was clearly indicated. Operation was performed, March 30, 1922, in the negative chamber, with general anesthesia. Torek's incision was made in the seventh intercostal space. The lower lobe was of the same, normal pink color as the upper, but, as a whole, more resistant on palpation. There were no adhesions whatever. For this reason, the original program of immediate lobectomy was abandoned in favor of a two-stage operation. The visceral pleura of the upper lobe and the parietal pleura

in the upper half of the chest cavity were thoroughly rubbed with a piece of sterile gauze. The upper lobe was then surrounded with seven iodoform gauze tampons, a piece of rubber dam enveloped the artificially collapsed lower lobe. The thoracic wound was carefully closed, layer by layer, by means of interrupted chromicized catgut sutures. The tips of the seven iodoform gauze tampons were tied with silk thread and buried below the subcutaneous fascia (Lilienthal). Air-tight drainage of the pleural cavity was not arranged for, as it was intended to use it for the second stage operation. The patient stood the procedure nicely, and passed a comfortable night. The next day there was a rise of temperature, rapid respiration and pulse, some dyspnea with cyanosis. Twenty hours after completion of the operation, aspiration of the pleural cavity with the needle and syringe filled the barrel with air, not fluid. The insertion of a small trocar, with an attached rubber tube, the tip being held under water, gave exit to a large amount of air. The dressing was well soaked with fluid wound discharge. After this, the patient was much improved. The next day the temperature was rising and aspiration was repeated, but neither air nor fluid was obtained. Change of dressing was accomplished under pharyngeal oxygen pressure. On removing the stitches over tampon tips, a large amount of serosanguineous fluid escaped. The tampons were quickly removed and air-tight drainage provided for, the tube being placed where the tampons had been removed. The patient passed into profound collapse when returned to bed and died six hours later, with rising pulse and temperature, in spite of stimulation of every possible type. Only wound inspection was permitted. Both lobes of the left lung were in complete collapse. There was no more fluid in the chest. The lower lobe, removed, showed a typical picture of bronchiectasis.

*Epilogue*—1 A one-stage operation should have been the choice in spite of absence of adhesions.

2 Evidently, a quickly increasing serosanguineous effusion, not reached by the aspirating needle, forced its way through the interruptedly stitched layers of the chest wall to the surface, allowing air to enter the pleural cavity, thus producing a hydrohemopneumothorax.

3 The continuous buried suture for the various layers of the chest wall seems preferable to interrupted sutures.

4 Air-tight drainage, added at the completion of the first stage of the operation, might have saved the patient. Had it been employed and had the patient survived the first stage of the operation, sufficient adhesions between the two pleural leaves over the upper lobe would probably have made air-tight drainage at the conclusion of the second stage unnecessary, or, in the absence of adhesions, retaining the patient under negative or positive pressure after the lobe resection for from one to two days, with the chest wound wide open, might have sufficed to bridge over the dangers of a flopping mediastinum.

#### COMMENT

The thoracic surgeon should also publish his negative results. In carefully analyzing the cause of death often much light is shed on

what might better have been done in a given case, and such reflections, jotted down by the individual man and published, will often be a guide to the workers in this new field of operative surgery in similar cases

The impression I have had from these operations and observation of these patients is

1 It is, it seems to me, the insistence on refining the diagnosis as much as possible and selecting the operative treatment on strict indication, carefully weighing the pros and cons before starting the operation, further, the absolute attempt on the part of the surgeon to avoid such accidents in the course of the operation as can be avoided nowadays by proper preparation, which will quickly further the advance of this branch of thoracic surgery

2 It should be explained to the patient who suffers from typical bronchiectasis, that bronchoscopic treatment and incision with drainage promise no hope, and life would continue to be a misery, therefore, the risk of radical operation, lobectomy, should be undertaken

3 It is not wise to enter the chest with a cut and dried program, to be carried out at all hazards, but rather to be guided by local findings as in operative procedures in other parts of the body

4 Every effort should be made to make lung excision a "one-step procedure" It stands to reason that it must be better for the patient not to be obliged to submit to a second operation soon after the first

5 If the one-stage procedure appears to be contraindicated, air-tight drainage is advisable after the first operation, in view of the marked tendency of the pleura quickly to produce a large exudate, especially when foreign bodies, such as tampons or rubber dams, have been left within temporarily It seems safest for the patient that this exudate which always occurs should drain off from the start The second stage of the operation, with the subsequent after-treatment, can then be conducted as in any other operation, viz, without differential pressure on account of the presence of adhesions Should the latter have failed to form sufficiently, and drainage appears again imperative at the completion of the second step, the temporary maintenance of the patient under differential pressure, as mentioned before—negative chamber, positive cabinet, positive oxygen pressure with the help of the mask, or any kind of suction apparatus—will effectively help out

6 We must learn how to reduce the ever imminent danger of aspiration pneumonia, subsequent to general anesthesia Sauerbruch considers general anesthesia a necessity for intrathoracic work and calls it a "technical mistake" to try anything else Yet it is to be hoped that means will be found in the course of time to do also the intrathoracic work, at least in certain cases of subacute and chronic lung suppuration, under some kind of local anesthesia, in order to enable the patient

to expectorate at will throughout the operation. Perhaps the filling of the chest with a nonpoisonous solution of a local analgesic, or a carefully worked out plan for regional anesthesia, will help, or, if such hope cannot materialize, a very superficially conducted general anesthesia, with an anesthetic that does not stimulate mucus discharge, as, for instance, anesthol or chloroform, or an expertly conducted general anesthesia with nitrous oxid and oxygen in the hands of a man who knows—"team work"—will do it. The third case of ligation of a branch of the pulmonary artery, done for typical bronchiectasis, reported above, was almost completely done under local anesthesia.

7 The principal points to be observed during lobectomy are (a) the safe sealing of the bronchial stump during operation—blood vessels and bronchus, (b) arrangement during the operation for meeting the dangers of the usually occurring bronchial fistula when the ligatures of the stump come off, the chest having been tightly closed.

In view of the fact that proper treatment of the stump is the principal point in lobectomy, and that it has been seen that experience gathered in experimental lung surgery cannot be transferred to human pathology in this field, separate ligation of the branches of the pulmonary artery and vein, with air-tight closure of the infected and impregnated bronchial stump, becomes inadvisable or impossible in man. The stump, therefore, is to be treated *en masse*. Friedrich<sup>11</sup> used for this purpose his hilum clamp. Others employed a mass ligature of silk or rubber, providing against the subsequent leakage by gauze tamponade, or they closed the chest and risked the consequences of the expected air leakage. Howard Lilienthal<sup>12</sup> of New York in his classical article on resection of the lung advises treatment of the stump with multiple penetrating silk sutures, piercing it repeatedly with needle and thread and tying the threads most carefully. Each ligature thus placed grasps and secures indiscriminately a portion of the stump. At the end of the procedure, the blood vessels and bronchus are found to be safely closed. He leaves the threads long, marks their collected ends by a safety pin and buries them temporarily under the skin, while the immediate after-treatment, wisely, is conducted under air-tight drainage. When the first days have passed, the wound is partially reopened, and the thread ends are exposed. They enable the operator to extract the gangrenous stump as a whole later on, when Nature has safely sealed the large divided blood vessels. The resulting bronchial fistula or fistulas usually close by granulation. The deeper it is situated, the greater is the chance of perfect cicatrization.

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<sup>11</sup> Friedrich. *Arch f klin Chir* 82 1171 1907

<sup>12</sup> Lilienthal, Howard. *Ann Surg* 75 257 (March) 1922

Surgeons, as a whole, will do best, it seems to me, to follow Dr. Lihenthal's carefully worked-out technic, because he has seen with it more actual recoveries than any one else in the world and has succeeded in reducing the mortality to 45 per cent, a splendid achievement.

Still, I believe that other methods of treating the stump can and will gradually be worked out, which will also prove useful. And this, I think, will happen as soon as lobectomy has come into more general use, and that, there is no doubt, will occur in the near future.

In my mind I have always compared the extirpation of the lung with that of the kidney, at least as far as the immediate treatment of the pedicle is concerned, and I could never forget in this respect the observation made by the late Professor Czerny of Heidelberg in his early cases of nephrectomy. At that time he was in the habit of securing the broad pedicle of a suppurating kidney with a needle and thread, perforating it as chance arranged it. One of the patients died from acute sepsis, although the wound had been properly drained. At necropsy it was seen that the needle had pierced the renal vein, and the ligature consequently gave a direct route for the bacteria to enter the circulation. Czerny attributed the fatal issue in that case to his method of stump treatment. From that time on, he used a mass ligature of strong material which surrounded the entire pedicle of the kidney a number of times. I should consider it also good surgery to compress temporarily the lung lobe stump, the bronchus and the blood vessels, with a useful, adaptable instrument, amputate the lobe, from  $1\frac{1}{2}$  to 2 inches (3.5 to 5 cm.) in front of the same, and then, after proper separate ligation of the visible cut ends of the blood vessels, disinfect and close, after the usual crushing, the bronchial stump, or cover it, in addition with retained lung tissue, as the surgeon may think best. Having watched the working and the many advantages of Sehr's metallic tourniquet in limb amputation,<sup>13</sup> I planned to try small metallic tourniquets, manufactured on the same principle, "Baby-Sehrs," in lung extirpation. So far, I have had three sizes made by George Tiemann & Company of New York, 5, 4 and  $3\frac{1}{4}$  inches from end to end (Fig. 3). I had them ready for use in my last case planned for lobectomy (Case 7), but did not have the opportunity to test their usefulness, because the absolute absence of adhesions made me, much to my present regret, decide on a two-stage operation. It is possible that these instruments will prove of value in the technic of some cases of lobectomy inasmuch as with them the pedicle can, by means of a thumb screw be compressed gradually and at will, just enough to control hemorrhage. If, on loosening the tourniquet, the control should prove incomplete a

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13 Meyer, Willy. *Ann. Surg.* 72:763 (Dec.) 1920.

turn of the thumb screw restores immediately the former safe condition of hemostasis. I am expectantly looking forward to my next case, in which I may test the device.

In conclusion, just a word regarding the necessity of the performance of necropsies in thoracic work. Here, as in other fields of thoracic, as well as of general, surgery, the postmortem examination, or at least a wound inspection, is most essential for proper progress. We MUST know whether pneumonia (usually due to aspiration during or after our work, eventually also due to loss of body heat, in consequence of prolonged exposure of the patient and his very large wound in too cool a room), or whether septic infection, consecutive to the surgeon's imme-



Fig. 2 (Case 3)—Typical postpneumonic lung abscess cured by incision. Localization not definitely determined before operation, free pleural cavity entered and lung adhesions made out by palpation from within, abscess aspirated at this place and incised at the same stage. The opened free portion of the pleural cavity closed by suture, air-tight drainage established, resulting in cure.

mediate work at the time of operation, or a hemorrhage, or a wrongly selected method of after-treatment, inviting infection, is responsible for the fatal issue. Only in this way will thoracic surgery make the safe and quick progress it needs. Also, for this reason, it is to be hoped that the cases of all patients operated on will be reported in the literature irrespective of whether they ended in recovery or death.

#### TUBERCULOSIS AND SYPHILIS

1 *Tuberculosis*.—It must be a comfort to patients suffering from advanced pulmonary tuberculosis, particularly those with cavity forma-

tion, to know that when all other specialties in medical science have exhausted their therapeutic possibilities, surgery may still bring help in from 60 to 70 per cent of the cases. The two-stage or three-stage extrapleural thoracoplasty is the operation of choice. It can be combined, if necessary, with apicolysis (loosening of the apex of the lung) plus fat (Tuffier), or paraffin (Baer) filling of the resulting cavity, or with flap formation and implantation of the pectoral muscles (Archibald), as well as with resection of the phrenic nerve, to produce paralysis of that half of the diaphragm. Placing the affected lung in

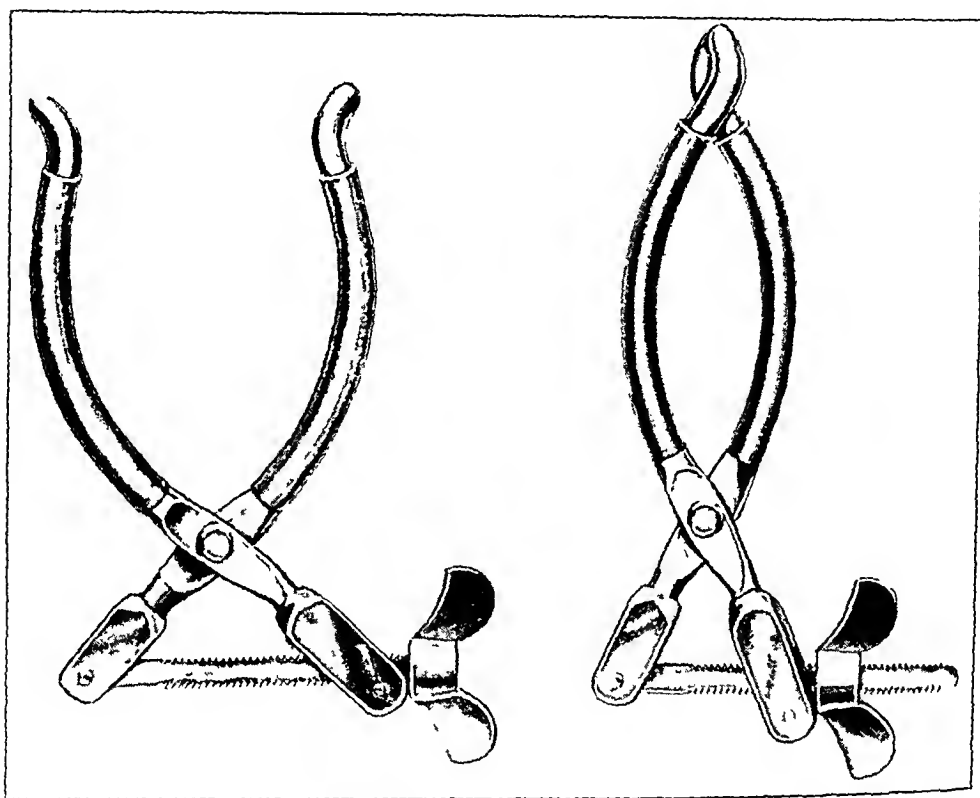


Fig 3—"Baby Sehrt" metallic tourniquet, designed for the compression of the pedicle of the lung in lobectomy, made in three sizes, No 2-4 inches illustrated here, about one fourth actual size

this way at perfect rest and compressing it as much as possible from all sides, with an elastic pad, after the rib resection, from without, paves the way to success. Massive connective tissue formation, substituting the affected lung tissue and encapsulating the tuberculous foci, explains the good results pathologically.

The work should be done under local and regional anesthesia if possible. Proper selection of the cases, in conjunction with a medical expert in lung tuberculosis, is necessary.

These patients should best be operated on in our general hospitals, which should put aside one or two rooms for this purpose. Careful

nursing with the strictest surgical supervision during the first days after operation is imperative

My personal experience covers four cases. Briefly stated, they are as follows

CASE 24—A man, aged 26, with an advanced case of bilateral affection in which the left was worse than the right, was operated on in two stages, Nov 18, 1918, and Dec 10, 1918, at the Lenox Hill Hospital. The ribs, from the second to the tenth, inclusive, on the left, were resected. The patient is cured and well at the present time. Tubercle bacilli, cough and sputum have disappeared. He lives in Texas, is in business, and engaged to be married.<sup>14</sup>

CASE 25—A man, aged 36, with bilateral far-advanced disease, was sent in from outside. He was desperate and begged for operation. Personal, wrongly placed humanitarian sentiments induced me to yield. Operation, first-stage, was performed in January, 1919, at Lenox Hill Hospital. The tenth to the sixth ribs were resected under regional and local anesthesia. The operation was well borne, but preoperative fever continued to rise. He returned to the mountains and died. Partial necropsy revealed pronounced disseminated (miliary) tuberculosis of the opposite lung, less pronounced on the side on which operation was performed. This was a rare occurrence after this plastic operation.

CASE 26—A woman, aged 35, was sent from outside with bilateral advanced multiple cavity formation. A New York specialist in tuberculosis whom I consulted was unable to say which side he should pronounce the more affected. Again humanitarian sentiments gained the upper hand, when establishing the indication. The first-stage was performed on the side first attacked by the disease, at the Montefiore Hospital, in May, 1921. The tenth to the sixth ribs were resected under local anesthesia. The operation was well borne. The patient was somewhat easier and under nurses' continuous observation. During the second-stage, June 18, when resecting the fifth to the second ribs, inclusive, further collapse of the lung produced dyspnea on the table which continued in spite of stimulation. There was no change in the hectic fever. Death occurred on the sixth day after the second operation.

*Epicrisis*—In this case, too, I wrongly felt that I was under personal obligations to the colleague who had sent the patient to me. I also had pity for the patient, for refusing the desired operation meant robbing her of her last ray of hope. Such sentiments, however, should not be allowed to confuse the surgeon's decision, strictest indication, built up on cold clinical facts, in consultation with a trained specialist in tuberculosis, is absolutely imperative in our attempts to treat surgically tuberculosis patients in the advanced stage of the disease.

CASE 27—A man aged 26, well preserved had diffuse bilateral tuberculous infiltration with no cavity. Paravertebral regional and local novocain-epinephrin anesthesia was used. The ribs from the eleventh to the fourth, inclusive were resected. Superficial general anesthesia was required for some time. Toward the end of an otherwise well borne operation, that had not been connected with



much loss of blood, sudden unexplained shock occurred, which continued. Subcutaneous stimulation and varied intravenous medication were of no avail. The patient died forty-eight hours after operation.

*Epicutisis*—Death was probably due to the paravertebral novocain anesthesia. Several deaths following this kind of anesthesia have been reported from abroad of late. I have abandoned it.

In an excellent article by Goetze<sup>15</sup> of Frankfurt-on-Main, recently published from Professor Schmieden's Clinic, the advisability of the resection of the phrenic nerve as a primary operation is emphasized. According to his experience, Goetze believes this operation has to "precede" extrapleural thoracoplasty and "should be added to every case of pulmonary tuberculosis, treated and improved with the help of artificial pneumothorax, before the patient is discharged from the physician's immediate attendance."

2 *Syphilis*—Lung suppuration in connection with syphilis is not a rare occurrence. Every patient with subacute or chronic lung suppuration needs a Wassermann test, and, of course, a negative result does not necessarily exclude syphilitic infection, should other symptoms point to its probable existence.<sup>16</sup> My personal experience consists of the following cases:

CASE 28—A man, aged 47, with far advanced lung suppuration, fever, tormenting, continuous cough with expectoration, in whom the roentgenogram simulated that of bronchiectasis, gave a four plus Wassermann reaction. He was seen in consultation, and strong antisiphilitic treatment was advised. Repeated arsphenamin injections were given, later intramuscular and mixed internal treatment. Today he is completely cured and active in business. He was presented before the meeting of the New York Society for Thoracic Surgery in November, 1921.

#### LUNG SUPPURATION DUE TO THE PRESENCE OF A BENIGN OR MALIGNANT TUMOR

1 *Benign Tumor*—This is usually situated within the lumen of a larger bronchus, where it acts, clinically, like a foreign body. Of this, I have had no personal observation.

Chevalier Jackson has seen twelve such cases, not counting one syphiloma, one tuberculoma and seven granulomas, the latter probably being considered secondary to existing suppuration. The twelve cases comprise one endothelioma, two fibromas, six papillomas, one edematous polyp, one cyst, one chondroma. Of these, the endothelioma had

<sup>15</sup> Goetze. *Klin. Wchnschr.* **1** 1496 (July 22) 1922, *ibid.* **1** 1544 (July 29) 1922.

<sup>16</sup> Landis, H. R. M., and Lewis, P. A. Latent Syphilitic Infection of the Lung. *Am. J. M. Sc.* **150** 195-200, 1915. Friedlander, Alfred, and Erickson, R. J. Syphilis of the Lung. *J. A. M. A.* **79** 291-294 (July) 1922.

caused suppuration. Inasmuch as the man is alive and well six years after operation, the growth has to be considered clinically benign, though histologically malignant. Of the remaining eleven, one fibroma, one papilloma and the chondroma were associated with suppuration, distal to their insertion, whether the suppuration was secondary or not could not be determined in every instance (personal communication).

Yankauer of New York reported a few such cases at the annual meeting of the New York State Medical Society, held in Albany, April 20, 1922, in which bronchoscopic removal of the growth (fibroma), once from the left, once from the right bronchus and once from the upper trachea, beneficially influenced the dependent lung suppuration.

## 2 Malignant Tumor—My experience comprises these cases

CASE 29—*Cancer of the right upper lobe, bronchiectasis, incision and drainage.* J. B., man, aged 45, was sent from outside on account of bronchiectatic symptoms of two years' duration which had greatly reduced his general condition and caused mental depression. A varying amount of sputum was expectorated which was of a rather sweetish odor. The roentgenogram revealed a diffuse opacity of the right upper lobe. Bronchoscopy was refused. Rib and intercostal soft tissue resection was performed under local anesthesia. A larger cavity was struck with the aspirating needle, opened and drained. The patient was more comfortable afterward, but there was no perceptible clinical improvement. He died, three weeks after operation. Necropsy revealed an infiltrating suppurating cancer of the lung which had caused the bronchiectasis.

CASE 30—*Lymphosarcoma and excision of right lung.* A boy, 5½ years. This case was reported under the heading "Lung Excision," as Case 21.

Yankauer<sup>17</sup> emphasizes the fact that spontaneous lung suppuration in middle-aged patients is not infrequently due to the breaking down of a malignant tumor of the lung. He found ten cases of this class among about sixty cases diagnosed as lung abscess (about 16⅔ per cent). Kully,<sup>18</sup> a former assistant of Yankauer, reports a malignant tumor as the cause of the purulent expectoration in ten out of ninety-two cases of suppuration (10.87 per cent).

## A FEW CASES DIFFICULT TO CLASSIFY

CASE 31—*Bilateral bronchiectasis.* An undeveloped girl, aged 9, expectorated from one-half to three-quarters of a basinful of very foul pus several times a day, at will. The roentgen rays revealed a shadow over both lower lobes, more on the right side. Operation was performed June 8, 1911. Reported thorough expectoration in the knee-elbow posture was accomplished before starting. General anesthesia (anesthol) was employed. Aspiration in various places drew no purulent secretion, but here and there the well-fitting and well-working piston of the record syringe pulled out with ease, the barrel filling with air, without being sucked in again by negative pressure. It was

<sup>17</sup> Yankauer, Sidney. *Tr. Am. Laryngol. & Otol. Soc.* 1920, p. 220.

<sup>18</sup> Kully, B. M. *Am. J. Surg.* 35:49 (March) 1921.

recognized that such easy aspiration of air corresponded in value to that of pus and presented sufficient inducement for the surgeon to incise the lung with the expectation of finding the cavity. On dividing the tissues with the cautery in the eighth intercostal space near the spine, the free pleural cavity was opened. The operating table was moved to the positive pressure cabinet and the pressure was turned on. When busy packing the wound for dressing, with the intention of waiting for refilling of the pus cavity for opening at the second stage, sudden collapse occurred, from which the patient could not be revived. Necropsy was not permitted.

*Epicutis*—If air is easily aspirated from a place where pus was drawn before by a reliably functioning syringe, particularly after the patient had thoroughly expectorated, proof is rendered that the cavity has been struck. Of course, it is recognized that in exceptional cases the tip of the needle can rest within the lumen of a bronchus and thus draw in air.

CASE 32—*Right bronchiectasis*. A woman, aged 26, had been operated on out of town several times before. The fistulas persisted. The roentgen rays revealed a small cavity communicating by a narrow canal with the bronchial tree. There were scant expectoration and scoliosis. She desired operative treatment, since she was a working girl. Operation was performed, Feb 8, 1913, under local and regional anesthesia. The cavity was laid open by resecting three ribs adjacent to the sinuses. Enlargement of the entrance was accomplished with the actual cautery, which opened a cavity communicating with a number of, as it seemed, partially occluded bronchi, except the one small communication with the bronchial tree seen on the roentgenogram. Tamponade of wound was employed for temporary conservative treatment. If desired, excision was to be performed, later on. There was no reaction. Ten days later, increasingly severe headaches, opisthotonos, strabismus, etc., indicative of suppurative meningitis developed, and the patient died. No necropsy was performed.

CASE 33—*Bronchiectasis of left upper and lower lobes*. P. C., with bronchiectasis on the left side, the left upper lobe being affected, with purulent material seen by the bronchoscopist also in the left lower branch, but which was considered to have run down, was operated on Dec 15, 1915. Exploratory thoracotomy was performed for possible excision in the negative chamber under general anesthesia. An oblique incision was made through the axilla forward, with resection of the second to the fourth rib, inclusive. The pleura was incised in the bed of the third intercostal space, the upper lobe of the lung was pinkish and had a number of infiltrated brownish areas. Enlarged glands were seen around the main bronchus. There were firm adhesions with the lower lobe. On trying to enter the interlobar space, lung tissue was inadvertently torn and the escape of some pus was observed. On bringing the diseased lower lobe more clearly into view, it, too, was found visibly involved. Access for total pneumectomy was insufficient. Deeming an immediate additional posterior incision with attack on both lobes unwise, the upper part of the wound was closed by layer sutures. Thorough drainage by means of two gutter tubes at the anterior angle was established, as well as an additional incision in the tenth intercostal space for free drainage. Differential pressure after-treatment was employed. The next morning, the temperature rose to 106 F, respiration 50, likely acute

pneumonia, with or without fulminant sepsis. For safety's sake, change of dressing under differential pressure, gave exit to some additional retained sero-sanguineous fluid which had thoroughly soaked the dressing. Stimulation had no effect. The patient died at 3 p. m., twenty-two hours after operation. Wound inspection or necropsy was not allowed.

*Epicrasis*—1 Lung excision of the lower as well as of the upper lobe requires wide access. The posterior incision (Torek) appears to be best for the purpose.

2 Air-tight drainage is likely preferable to free incision in combination with drainage under differential pressure.

3 In the light of present experience, bolder advance, viz., excision of the entire lung at one sitting, provided the operative attack had been decided on, would likely have given this patient a better chance.

CASE 34—*Right bronchiectasis*. A man, aged 23, with right bronchiectasis, had been sick for several years. There was continuously a large amount of sputum. A two-stage pneumectomy was planned, first, extrapleural thoracoplasty combined with intrapleural pneumolysis and tamponade, leaving the patient for a while under differential pressure after-treatment, in order to try to produce adhesions around the hilum and reduce the reflex sensitiveness of the pleura, second, from one to two weeks later, excision of the lobe, if possible under local anesthesia. Operation was performed May 7, 1915, in the negative chamber, begun with the door open. Regional and local anesthesia was used, later on general anesthesia was required. Sauerbruch's hook incision accomplished resection of the seventh to the first rib, inclusive, beyond the angle up to the spinal column. When working at the first rib, the pleura tore, air rushed into the pleural cavity and out. The door of the chamber was closed and differential pressure started. The external posterior incision was lengthened forward, penetrating the seventh intercostal space. The lung was found totally adherent, and stripped off. The patient at this time was somewhat cyanotic. The color was not improved after artificial respiration, carried out within the chamber, therefore the operation was discontinued. The lung was covered with a sterile rubber dam and gauze tampons. The posterior wound was sutured, and a gauze tampon was placed in the pleural tear at the first rib. Differential pressure after-treatment was employed, with the patient on the operated side. After twelve hours, the pressure was turned off. The patient's condition was good. He was moved to the observation room, and the upper part of the body was raised. Three hours later, a sudden change occurred in his condition, and death followed a few minutes later. Necropsy and wound inspection were not permitted.

*Epicrasis*—1 Perhaps the patient was removed too soon from the differential pressure apparatus. Acute collapse of part of the lung may have caused the sudden change.

2 Tamponade of the pleural tear at the first rib was a technical mistake. The posterior wound should have been closed entirely in the upper part by layer sutures, in spite of the necessity to leave the lower part of the wound open. Differential pressure after-treatment should

have followed just the same. By the time the patient was removed from the pressure cabinet, the pleural tear had likely been sealed air-tight.

### C BRONCHIECTATIC LUNG ABSCESS

*Tissue defect, due to local gangrene, usually without progressive symptoms.* As stated above, I feel inclined to believe that this class of subacute and chronic lung suppuration is typical for cases of aspiration of septic material of semisolid and liquid character. The aspirated material will, I believe, rarely, if ever, produce "typical bronchiectasis."

1 *Specialistic Treatment*—To repeat what cystoscopy and ureteral catheterization, inclusive of the use of the operating cystoscope, accomplishes in urinary surgery, bronchoscopy accomplishes in the early and later treatment of certain suppurative pulmonary diseases.

*Bronchoscopy (Peroral Endoscopy)*—(a) For the extraction of aspirated foreign bodies, stretching of bronchial strictures due to inflammation, removal of benign tumors, punching out bits of tissue from seemingly malignant growths for microscopic examination, etc.

I have had numerous personal experiences in this class of cases, collected by observation, first in the practice of Dr. Sidney Yankauer of New York City, and later in the bronchiectatic clinic of the Lenox Hill Hospital, conducted by the late Dr. Henry L. Lynah and Dr. Richard Jordan of New York, now by Dr. Jordan and Dr. John D. Kernan, Jr. However, I must refrain from reporting them. I believe that the digest of this part of the bronchoscopist's work, particularly with reference to the stretching of bronchial strictures, the cauterization of granulations, injection of bismuth oil, antiseptic solutions, etc., into the pulmonary cavities for diagnostic as well as therapeutic purposes, belongs to the domain of the specialist.

I shall report here just one personal observation of a foreign body in the trachea that refers to lung suppuration.

CASE 35—H. H. T., a physician's son, had a continuous cough for years, with purulent sputum commencing after an attack of typhoid fever ten years before. He needed tracheotomy and is still wearing a silver tube. He was brought up on a stretcher from the South in the summer of 1916. After clinical and roentgen-ray examination, bronchoscopy, as in every other case, was performed, as a routine practice (Dr. Yankauer). The tube was introduced through the tracheotomy-fistula. Two irregular foreign bodies were seen and extracted from near the bifurcation. They proved to be sequestrums of thyroid cartilage. The cough was immediately much improved. At the request of the father, the patient was allowed to return to the South. From the report of the family physician, August, 1922, it was learned that the patient was in very good health, no cough, had gained about 30 pounds, and was feeling perfectly well. He still had the tracheal fistula.

It deserves to be emphasized that a timely extraction of a solid foreign body from the bronchial system can quickly improve and cure a patient, threatened with or already suffering from the inevitable consequence of its presence suppuration

(b) *Prompt, early suction in case of septic lung infection, due to aspiration during nasopharyngeal and other operations under general anesthesia, or to a swim in infected waters with aspiration of such water, also to aspiration during stomach lavage, etc*

Of the beneficial effect of early, I might call it "prophylactic," suction, I personally can record two cases

CASE 36—*Beginning severe lung suppuration subsequent to aspiration of stomach contents during operation* A man, aged 46, had had an appendectomy plus a cholecystectomy performed by me in October, 1920, under general anesthesia In the course of the operation, the patient vomited and stopped breathing Cyanosis developed, but prolonged artificial respiration restored normal breathing The first two days of the after-treatment were undisturbed, then a rise of temperature occurred with prolonged chills, persistent, most violent coughing spells and typical sputum The patient was very sick, requiring strong stimulation and careful nursing As soon as possible, with high fever still present, he was transferred to Lenox Hill Hospital Prompt bronchoscopy with aspiration (Lynch) was performed and continued at regular intervals for many months (six) Two distinct, small abscess cavities were revealed, closely adjacent, with the fluid level visible in the roentgenogram The patient and family were opposed to operation During the last year, endobronchial treatment was used with longer intervals Today the patient is perfectly well, with no cough, or sputum Clinical examination was negative Roentgenologist's report "Nov 21, 1922 The lung abscesses in the right upper lobe have apparently completely disappeared"

CASE 37—L. A., a woman, aged 28, had undergone bilateral tonsillectomy at another hospital Three days later fever and cough began One week after operation, the patient expectorated distinctly dark, foul-smelling coagulated blood On the fourteenth day after the operation, the patient came under my care, with distressing, continuous cough, fetid sputum and high fever Almost all food was regurgitated in consequence of the paroxysmal phrenic convulsions of the stomach There was right upper lobe affection She was admitted to Lenox Hill Hospital, April 7, 1921, viz., three weeks after the tonsillectomy Bronchoscopy by Dr. Henry L. Lynch revealed acute edema of right bronchus and suppuration from the right upper lobe bronchus Thorough cleansing of the bronchial tree was accomplished by suction The cough stopped as by magic, the temperature soon dropped to normal, and the appetite returned The patient considered herself completely restored to health and left the hospital against advice, after one week She was lost sight of, but traced by the hospital's social service nurse, whose report, dated April 19, 1922 reads "Patient in perfect health no cough, no sputum"

*Comment*—To my mind, the therapeutic, one might say "magic," result in this *early stage* of serious commencing suppurative lung infection subsequent to tonsillectomy represents a most important observation

For a long time, we had been waiting for just such cases. The task was to find out whether early thorough removal of the infectious material by suction could possibly mitigate or cut short advancing suppuration.

Already at this early date in the evolution of this branch of thoracic surgery which promises so much, one likely will not go wrong in saying that results will run parallel with the time of suction, viz., the length of the interval between accident and suction, and the degree of virulence of the aspirated material. It is to be assumed that stomach contents will usually be more infectious to lung tissue than aspirated blood and mucus. This has been proved clinically by untold observations, inasmuch as so many cases of aspiration-pneumonia, subsequent to vomiting in the course of general anesthesia, have proved fatal.

The following four similar cases of this type I owe to the courtesy of Dr. Jordan, and they are here published with his permission.

CASE 38—C. H., a woman, aged 26, in the fall of 1918 had influenza, followed by a persistent cough for more than a year. In the winter of 1919 she had several attacks of tonsillitis. March 2, 1920, the tonsils were enucleated under ether, one day was spent in the hospital. Two to three days later, while working, severe pain occurred in the left side of the chest, fever, and rapid breathing. March 11, she was seen in consultation by Dr. Jordan. The patient was critically ill, with all the symptoms of an acute suppuration in the left upper lung lobe. The sputum was foul and bloody. The stormy onset of the attack subsided within a week, but the pulse remained weak and rapid and the expectoration profuse and foul. April 7, five weeks after tonsillectomy, she was transferred to the Lenox Hill Hospital. The general condition was still poor, expectoration amounting to 250 cc. in twenty-four hours.

Physical examination (Dr. Schwerdtfeger) confirmed the diagnosis "lung abscess," which also showed plainly on the fluoroscopic screen in the roentgenogram. First bronchoscopy was performed April 9 (Drs. Lynah and Jordan), a 7 mm. Jackson tube being used. There was a profuse flow of pus through the tube. On entering the left bronchus there appeared an edematous stenosis of the upper lobe orifice, a small opening from which free pus was expelled with each cough. In addition, a membranous plaque was present, which also obstructed drainage from the upper lobe. The slanting end of the tube was gently introduced into the orifice, separating the edematous structure. The membranous plaque was removed by suction. The lower lobe branches were then examined, but no pus was found. Second bronchoscopy was performed two weeks later. The orifice seemed somewhat wider, expectoration was still profuse. With the curved spiral cannula, 8 cc. of bismuth subcarbonate in olive oil, 5 per cent, was injected. This bismuth could afterward be seen on the roentgenogram within the abscess cavity, although a portion had leaked down into the lower lobe branches. At the third bronchoscopic treatment, April 28, the injection of bismuth-oil was repeated. May 6 (fourth bronchoscopic treatment), decidedly less pus came from the affected bronchus, and the odor was hardly perceptible. The patient continued to improve visibly under weekly bronchoscopic treatments and was discharged, May 29.

She went to the country for about two months and came back fully restored to health. A roentgenogram taken in the fall of 1920 showed the left lung cleared up, except for a remnant of the bismuth in the upper lobe and in the lower lobe branches. According to a recent report by the attending physician, the patient is now in excellent health and is entirely free from cough and expectoration.

CASE 39—W. C., a man, aged 51, eight years previously had beginning diabetes. Four years previously he had pneumonia on the right side, and was sick for seven weeks. Alcohol had been used freely, until recently. He had a fistula in ano, with several attacks of abscess formation, and he had lost weight within the last three years. The present illness began suddenly, three weeks previously, after an overdose of eating and drinking. The patient awoke with vomiting and gagging, probably caused by aspiration of vomited material at that time. Excessive coughing, with pain on the left side, followed by profuse expectoration, set in and continued.

He was admitted to Lenox Hill Hospital, Oct. 28, 1921. He was still fairly well nourished, very sick, coughed constantly day and night, and had profuse expectoration with a foul odor, a fever of 102 to 103 F. The left lung showed extensive bronchial râles, dullness over the upper portion of the lung, in one area, distinct amphoric breathing. The right lung was normal. The roentgen rays revealed two definite cavities, the upper, corresponding to the sixth interspace, was the larger, with a fluid level. The smaller one was in the eighth interspace. Antidiabetic treatment and sedatives were used. November 14, aspiration, with a needle and syringe, was negative. December 3, the second roentgenogram revealed the same findings. The smaller cavity did not contain any fluid, while in the larger one a "fluid level" could be distinctly seen. No special improvement occurred under treatment. Cough and expectoration continued. December 3, bronchoscopy (Drs. Lynah and Jordan) revealed "Edematous swelling at the orifice of the left upper lobe bronchus. It is possible to pass this stricture with a 7 mm. bronchoscope. Profuse discharge of mucopus follows the stretching. All other lobes free." Bronchoscopy was followed by marked and immediate improvement. Cough and expectoration were much less after a few days, sleep and appetite were better. December 15, second bronchoscopy (Dr. Jordan) revealed "Appearance of orifice of left upper lobe shows a decided change. Edema has almost disappeared, orifice is wide, discharge much diminished. The patient improves steadily and rapidly. He was discharged from the hospital, December 23, and went to the country. All symptoms disappeared within a few weeks. Today, aside from a small amount of sugar in the urine, the patient is perfectly well and working, as usual. The left lung has cleared up, all physical signs have disappeared.

CASE 40—C. E., a man, aged 24, was admitted to Lenox Hill Hospital June 18, 1920. Tonsillectomy under ether was performed, June 5, 1920. Cough and fever developed six days afterward, expectoration, three to four days later. Physical examination pointed to a lesion in the right upper lobe (Dr. Schwerdtfeger). Roentgen-ray examination revealed a "triangular dense area surrounding a cavity with a fluid level and air bubble" (Dr. Stewart). Foul expectoration, about 500 cc. was produced daily. Bronchoscopy, June 29, 1920 (Drs. Lynah and Jordan), revealed copious discharge of foul pus from the right upper lobe only, bronchial orifice, edematous, 10 cc. of bismuth mixture injected. Second bronchoscopy was performed, July 8, and the bismuth injection repeated, followed by immediate roentgen-ray examination. 'Bismuth



was seen outlining numerous cavities" (Dr Stewart) The quantity of sputum rapidly diminished and had practically disappeared at the third bronchoscopic treatment a week later The patient made a complete recovery and is perfectly well today (Reexamination by Drs Schwerdtfeger and Stewart in June, 1922)

CASE 41—A H, woman, aged 28, was admitted to Lenox Hill Hospital, April 30, 1922 Five weeks before admission, tonsillectomy had been performed under ether Cough and expectoration occurred a week later She had been expectorating about a pint of foul pus daily Roentgen-ray examination, May 2, revealed "extensive density in the right upper lobe, showing a cavity with air bubbles Findings are distinctly those of a large, single pulmonary abscess" (Dr Stewart) First bronchoscopic examination, May 4, 1922, revealed foul discharge from right upper lobe only, very copious, bronchus distinctly obstructed by edema, 20 per cent silver nitrate solution applied The patient was treated bronchoscopically with the application of silver nitrate and injections of a silver preparation, first, every week, then every two to three weeks, altogether seventeen times, until October 26 A distinct improvement was seen after the third and fourth treatments, and the patient has improved steadily since then There has been no secretion from the infected bronchus since September 28, and the patient feels perfectly well today The recovery is confirmed by the roentgen-ray findings

*Comment*—If suction alone, or combined with local treatment, by means of bronchoscopy, can produce such remarkable clinical results a few weeks after the aspiration of septic material, it is not difficult to imagine that bronchoscopy with aspiration, as early as possible after the onset of lung symptoms, viz, as soon as the general condition of the patient permits, will reveal still more fulminant improvement Case 37 proves this One single thorough aspiration cured the patient There is no doubt in my mind that not surgery in any form, inclusive of the artificial collapse of the lung, is primarily indicated in these terrible cases, which still occur so frequently, but bronchoscopy, with thorough aspiration, without or with local antiseptic treatment

(c) *Regular suction treatment, with intrabronchial chemical application and irrigation, as well as mechanical treatment (dilatation, etc) of the affected stem bronchi, in cases of lung suppuration of long standing*

CASE 42—V B, a girl, aged 14, had been well until she underwent a tonsillectomy in the spring of 1914 A few days later, signs of beginning lung suppuration, with the usual concomitant symptoms, set in The patient was very sick, and was treated expectantly for many months, at her home on the coast At last the attending physician decided to send her East for relief While crossing the continent, she was very ill, with high fever The relatives that accompanied her expected her death on the train The sudden evacuation of a large amount of pus gave great relief On her arrival in New York, where she came under my care, she was admitted to Lenox Hill Hospital The general condition was much improved Clinical observation and examination failed to reveal positive signs of abscess, cough with expectora-

tion having abated, but the roentgenologist interpreted the details of the roentgenogram as cavity with the fluid level in the right upper lobe. No operation was advised. The patient was sent to the country where great improvement occurred. In the fall of the same year, she suffered a recurrence. Bronchoscopy revealed all three lobes responsible for the purulent expectoration. Endobronchial treatment was advised and carried out by Dr. Yankauer, weekly, about thirty-two treatments being given from September, 1916, to May, 1917. Gradual convalescence followed. Today the patient is on the stage and enjoying life.

CASE 43—A man, aged 20, had pneumonia involving the right lung in 1918. Four weeks afterward, inflammation set in, and he began to cough pus. The diagnosis was lung abscess in the middle lobe. About six months later, he was referred to the bronchoscopic division of the Lenox Hill Hospital. Pus was seen to ooze from the right middle lobe. Many granulations had formed, causing stricture of the stem bronchus. Stretching of the stricture was followed by cauterization. Regular treatment was carried on there for more than eight months, once weekly, with gradually lengthened intervals. Off and on, recurrent attacks of fever, with hemoptysis and increased sputum, were regularly followed by improvement after bronchoscopy within from five to six days. Today the patient is back at work. There are no further clinical signs of chronic inflammation. The report of the roentgen-ray department, Oct. 26, 1922, was as follows: "The entire right lower lobe shows extensive fibrosis and thickening of the pleura. The right lower main bronchus is considerably dilated. There is some evidence of minute cavitation. The roentgenographic findings would not indicate permanent improvement. I feel confident that this patient is liable to exacerbation if subjected to any unusual exposure." (I owe permission to publish the report of this case to the courtesy of Dr. Torek of the Lenox Hill Hospital, in whose care the patient was on the ward.)

CASE 44—A woman, aged 26, on whom bilateral tonsillectomy had been performed under general anesthesia, four years previously, ten days later developed all the symptoms of lung suppuration. She had four operations at another New York City hospital. At the first and the fourth, pus was found and the cavity drained. She entered the Lenox Hill Hospital in May, 1920, with symptoms of lung suppuration. The first bronchoscopic treatment was given May 25, 1920. Since then, until March, 1922, it has been repeated with thorough aspiration about thirty times. At first, a great deal of secretion seemed to come from all three lobes of the right lung. The stem bronchus was greatly obstructed by granulations, making it difficult to localize the sources of secretion, which was always copious and very putrid. Repeated dilation of the bronchus was performed, together with the injection of bismuth oil, 5 per cent, and the application of silver nitrate, etc. The bronchoscope revealed gradual and considerable improvement. The principal amount of pus formation came from the middle lobe. She was well in the summer of 1920, having little secretion. In the fall, she suffered a relapse and was again improved by the same treatment. Since that time, ambulatory treatment has been given since the patient lives out of town. The immediate effect of the bronchoscopic cleansing was always very marked. The last relapse occurred in the fall of 1921, and she was readmitted to the hospital for the same treatment. At the last examinations in February, 1922, no secretion was seen at any time. The patient was free from all symptoms, and seemed perfectly well. She went to Ireland on a visit for the summer on her own initiative,

from where she wrote under date of July 18 "Since I got home I am feeling just fine All trace of my illness has left me I feel just as strong as ever in my life, except if I run very much I get out of breath quickly I can ride a bicycle, enjoy rowing a boat, dancing and all the pleasures I used to enjoy before I got sick" (Of course, the patient had been strongly advised against risking such stunts) "I can even work in the hayfields I was working for two months before I sailed, May 27th, and felt fine, even when I was working in the country I felt myself improving I really think that having my lung washed out started it healing"

The present condition of these three patients, whose cases are reported under *c*, can certainly be called "much improved" <sup>18</sup> Naturally, not all patients derive the same benefit from this regular intrabronchial treatment, usually done once a week Some were but slightly improved, others, not improved, left the hospital, refusing operation I know that a few of the latter are still alive, leading an existence of misery, or have died, later on, at their homes without operation Experience will have to show whether more frequent treatments, than once a week, for a certain length of time, can do more good in advanced and obstinate cases

#### COMMENT

1 The different result, obtained by intrabronchial specialistic treatment, is explained, to my mind, principally by the pathologic variety of pulmonary suppuration It cannot do much good in typical multilobar bronchiectasis for obvious reasons It may, perhaps, alleviate the symptoms of these patients, and also, likely, temporarily reduce the fetid odor and the quantity of their sputum, but it cannot possibly bring about a cure

The treatment promises better results in circumscribed suppuration, the so-called bronchiectatic lung abscess, also, it seems, in cases that had been incised by the surgeon without definite improvement, where, however, increasing connective tissue formation favors Nature's constant endeavors to bring relief

It stands to reason that in this class of disease the greatest use for intrabronchial specialistic treatment is in the prophylactic field, as already emphasized before, to cut short the threatened spread of the suppuration within the bronchial tree and the adjacent lung tissue, or to alleviate the severity of the infection by the early actual removal of aspirated and decomposing foreign substances from the bronchial tree, a task which cannot be accomplished by any other method of treatment The cases cited above prove this contention

It seems significant in this respect, that a single bronchoscopic suction treatment, given three weeks after the tonsillectomy, was capable of curing a patient with beginning lung suppuration due to the aspiration of septic material, that a number of aspirations (two, three and

more), done at intervals of from one to two or three weeks, combined with intrabronchial applications, were required, when the treatment began weeks (twice, three and one-half, twice, five and one-half, six and eight) after aspiration,<sup>19</sup> and that this kind of specialistic treatment, extending over months and years, is required to bring more definite improvement, when the trouble has existed for months and years.

It now will become necessary to corroborate the favorable observations so far obtained by a larger series of successful cases.

2 Regarding the use of bismuth oil, 5 per cent, I do not venture to pass an opinion, it would be premature. In one case, reported below, the repeated injections, done most dexterously with the help of specially constructed ingenious instruments, impressed me as likely having complicated the pathologic picture (Compare Case 49 under "Operation for Bronchiectatic Lung Abscess"). On the other hand, several patients in whom it was used early, were promptly cured.

3 It will also be interesting to find out whether antiseptic lotions used with intrabronchial treatment can dissolve fibrinous coagulations and grumous material, which usually are found within the bronchiectatic abscess cavity.

4 In order to try to find the exact time when patients thus afflicted should be subjected to operation, all patients of this class who were admitted to my service at the Lenox Hill Hospital during an entire year (1920-1921) were first turned over to the bronchoscopic department for treatment. A trying time, to be sure, for the operating surgeon, but considered necessary in order to study definitely the possibilities of endoscopic treatment in this class of cases. If, after a lapse of from six to nine months or more, improvement was unsatisfactory, a joint consultation of endoscopists, roentgenologist, internal consultant and surgeon was held, and an attempt was made to establish the indication for further procedure, whether it appeared right and wise to continue the specialistic treatment, or whether the operating surgeon should take over the care of the patient.

In view of the results obtained and the improvement in the diagnostic classification of patients afflicted with lung suppuration, we now intend to try to segregate these patients soon after their admission to our hospital, advising, from the start, bronchoscopic treatment or operation, or, eventually, both combined.

5 There is no doubt in my mind that bronchoscopy is in the very beginning of its clinical usefulness. Who knows—and I should like

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<sup>19</sup> With reference to this point, Wessler's statement (*J A M A* **73** 1918 [Dec 27] 1919) must be taken into consideration that in 33 per cent of all cases of acute pulmonary suppuration following tonsillectomy the patients recover spontaneously within two months.

to repeat here the words expressed in the early pages of this article—whether the future will not see the trained bronchoscopist also join hands with the internist in fighting typical cases of pneumonia, obstinate in their convalescent stages. It will need courage to do so, but if once started and perhaps if it brings relief in certain difficult cases, the foundation for this team work will have been laid.

2 *Operative Treatment*—This may be either conservative or radical.

(a) *Conservative*—The operation of choice consists in the establishment of a temporary or permanent lung lip (bronchial) fistula for prolonged drainage and free ventilation of the infected portion of the lung.

(b) *Radical*—If the surgeon or (and) the patient do not want to select the slower, and often more roundabout, procedure of lung fistula establishment, but prefer radical work, lobectomy must be performed.

Before reporting my cases treated with the help of a lung lip fistula, a word should be said concerning the term "lung lip fistula" in contradistinction to bronchial fistula.

We call a bronchial fistula the visible or audible opening of a bronchus, or of one or more of its divisions or subdivisions. The opening is round, sharp-cut, often so small as just to allow the introduction of a probe, but permitting exit and entrance of air, or it is longitudinally or obliquely shaped, etc.

The lung lip fistula, on the other hand, represents the entrance into a visible cavity within the lung and provides for the prolonged or permanent drainage and ventilation of this cavity, which is the result of a bronchiectatic lung abscess. It is artificially arranged for during after-treatment by continuously keeping the pulmonary wound filled with gauze, after incision of the abscess, so that skin cannot join skin, but the latter's border is forced to unite with that of the opening leading into the lung.

CASE 45—In 1911, I operated on a young woman, a physician's wife, who had developed an aspiration pneumonia subsequent to an ovariectomy performed under general anesthesia. After several weeks, she came under my care. Roentgen rays corroborated localization in the right upper lobe, showing multiple small cavity formations, fever, continuous cough with very fetid expectoration. Under regional and local anesthesia, resection of the second and third ribs with the intercostal tissue was performed. Aspiration in the rib bed revealed pus. The abscess was opened about 2 inches below the surface of the lung. It was filled with irregular, partially also round, coagulated masses of fibrin and detritus of the same foul odor as the sputum. The finger when introduced detected a second abscess cavity "around the corner." Prolonged drainage and tamponade was instituted with gradual improvement. The patient returned home under her husband's care. He removed the drainage tube after some time, and the wound healed. Three months later, the symptoms returned. The lung cavity had to be reopened and drained, but this time I kept

it open for six months. The foul odor of the sputum again completely disappeared. Later on, I was told by the husband that the tube slipped out of the wound and could not be reintroduced, and the fistula closed, never to reopen. Today the patient is completely cured, without odor of breath, cough or sputum.

With the experience of the case just reported in mind, in my next case, I did not allow the external wound to close at all, but arranged for the formation of a lung lip fistula.

CASE 46—H. W., aged 26, a school teacher, following an attack of what seemed to be lung inflammation, not due to aspiration, pneumonia or influenza, had developed a pronounced pulmonary suppuration. He had been under the care of several colleagues and was finally declared consumptive, though tubercle



Fig. 4 (Case 46)—Bronchiectatic lung abscess of the left upper lobe due to nonprogressive local gangrene of the lung, clinically cured by permanent, thorough and direct drainage and ventilation of the irregular large cavities, with the help of a lung lip fistula, produced at a two-stage operation under local anesthesia.

bacilli had never been found in his sputum. With his family, he went to the mountains for many months, but did not improve. His sputum became so offensive that he had to be isolated. He occupied a room on the first floor, with the windows always open. His parents asserted that the veranda below was often uninhabitable after the patient had expectorated upstairs. He lost considerable weight and finally developed a small abscess over the third left rib in the mammillary line, which was lanced by the local physician. In this deplorable condition he came under my care in November, 1916.

After thorough examination and brief observation, the primary indication seemed to be better drainage. This was established under local anesthesia. During the interference the exploring finger determined the seat of the sup-

puration to be intrapulmonary, not also intrapleural, as might have been possible. As soon as the patient had improved somewhat and his temperature subsided, the operation for the permanent ventilation of the diseased area within the lung was carried out. The operative plan was to resect the overlying rib as far as required and then arrange for a lung lip fistula. This could be nicely done. Under local anesthesia, a goodly portion of the third rib was removed and a large hole leading into the adherent lung exposed. As the patient's left arm was tied down by the chronically inflamed pectoral muscles, which prevented him from raising it beyond the horizontal line, the belly of both muscles was split transversely, down to the ribs and up to the subclavian vessels, so that the two portions of them could retract thoroughly. Then the skin edges were stitched and placed in such a way on either side of the wound leading into the lung that the formation of the lung lip fistula had to result. From this time on the patient made an uninterrupted and most satisfactory recovery, except that once he had a rather sudden profuse hemorrhage from the lung fistula, which, however, could be controlled by tamponade through the opening, and further, that the removal of a gangrenous appendix became necessary. By making him breathe in through the fistula, as described above, and having the nurse, after removal of dressings, direct a current of pure oxygen from the tank into the lung several times during the day, the patient meanwhile keeping his mouth closed and the nostrils compressed, the terrific odor of the sputum quickly disappeared never to return, and the discharge from the wound also ceased completely.

Today he holds a responsible position in a bank in the northern part of the state and is married.

A slight reappearance of the old symptoms in milder form sets in only when, against strict orders, he "jumps the fence" and dances, rides the bicycle or plays tennis. He was warned against going out in a boat, yet he became an ardent fisherman last summer. If his boat ever capsized or if he should fall into the water, it would mean instant death.

According to a letter received in July, 1922, he had, after great mental excitement, a sudden profuse hemorrhage from the lung which stopped spontaneously and did not materially influence his general condition.

To my mind, this case proves that a far-advanced bronchiectatic lung abscess, representing a number of larger and smaller communicating suppurating cavities, can be brought under complete control by thorough direct drainage to the surface and permanent ventilation.

The observation of the gradual convalescence of this patient convinced me that there is "something" in this conservative method of operation, the conservatism in this instance having been forced on the surgeon by the much reduced general condition of the patient. Lobectomy certainly was out of the question. The point of this operative treatment is to see to it that every cavity drains to the surface thoroughly and directly. Today I am still more convinced that the method is a useful one, after having seen and examined this patient, whose case at the time of operation seemed almost hopeless (Fig 4). It is extremely interesting to look into this "dead crater," six years after the operation, under good illumination with an electric light carried at the tip of a wire

introduced into the depth of the lung. The same central cavity exists, and lateral cavities communicate with it, with a dry surface and blood vessels pulsating and shining through the many dividing walls diaphanously. And the patient has neither cough nor expectoration, and the expired air is odorless. He is cheerful, energetic and able to work.

The cavity, of course, cannot contract, as the lung is completely adherent to the parietal pleura, a fact which explains, to my mind, why, now and then, under particularly increased blood pressure (undue exercise, mental excitement, etc.) a hemorrhage sets in.

To cure the patient completely today would, of course, require the excision of the diseased portion of the lung, here the left upper lobe. However, I cannot find the indication to propose it, as it might easily prove disastrous, besides, the patient will not consent to it. But do not some patients have to carry a renal fistula throughout their lives, if, for example, the condition of the opposite kidney forbids nephrectomy?

A somewhat milder course of operative treatment, which eventually might also bring the cavity to a close, would be extrapleural thoracoplasty in the upper portion of the left side of the thorax, with circumcision of the fistula and closure of the hole by suture, the latter to be done at a second stage, some time after the first.

This case again proved to me a phenomenon I had seen before and commented on in presenting such patients before various medical societies, namely, that these suppurating lung cavities evidently are inhabited by "partially" anaerobic bacteria (probably saprophytes), that were responsible for the terrific, indescribably foul odor, and live and multiply because of the insufficient physiologic ventilation through the trachea and bronchial system, but perish as soon as "volumes" of air and oxygen have direct and unobstructed access.

This was the first patient with a chronic nonspecific lung suppuration, who was intentionally operated on and treated with the formation of a lung lip fistula. Since then, three more patients, equally afflicted, were similarly treated, and two of them also cured of the suppurative lung inflammation.

CASE 47.—A man, aged 40, a chauffeur, came under my care not long after. Immediately after an operation for circumcision under general anesthesia (ether) in June, 1916, a bronchiectatic abscess developed in the right upper lobe. A rise of temperature reaching 104 F., set in soon after the operation and lasted for four weeks. One week after the operation, he began to cough, and then for the first time he felt a sharp pain in the right axilla, with symptoms of dry pleurisy. He then went to the Adirondacks where he did some light work. In the fall of 1917 increased temperature was noticed and a foul odor to the sputum. Almost constant cough and expectoration developed, the latter of a very offensive rather sweetish odor, varying in amount from 16 to 24 ounces in twenty-four hours. It did not contain any elastic fibers or tubercle bacilli. Physical examination revealed fine rales over the right third rib also.



some indefinite fine rales over the lower chest on the right side. The left lung was normal. The roentgen rays revealed marked cloudiness of a patchy character throughout the upper three fourths of the lung, more marked in the middle third, some stringlike shadows visible throughout this cloudiness, and a peaked diaphragm. A nonspecific suppurating focus in the upper right lobe was diagnosed, and the patient sent to me for operation. In January, 1918, under regional and local anesthesia an incision was made slightly convex downward, in the second intercostal space. The major and minor pectoral muscles were divided, incising a portion of each perpendicularly to its fibers later on in order

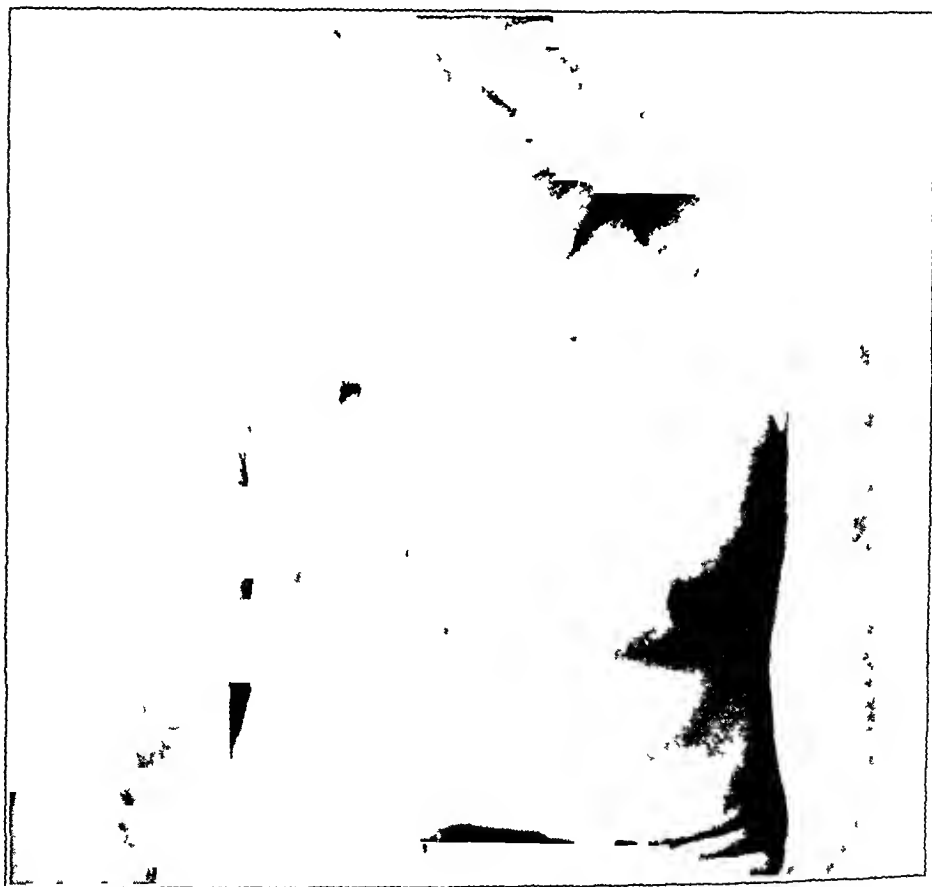


Fig 5 (Case 47) —Bronchiectatic lung abscess of the right upper lobe, due to aspiration during general anesthesia for circumcision. Pneumotomy was performed under local anesthesia, arrangement being made for the establishment of a lung lip fistula, which still persists after four years. The lung trouble is cured, and the patient is opposed to having the fistula closed.

to gain sufficient space. Resection of 4 inches of the second rib was performed. Careful division of the intercostal muscles proved that the lung was not moving, the pleural leaves being evidently adherent.

Aspiration was performed with a long needle of large caliber in the bed of the resected second rib, the needle being pushed on in a straight direction backward, with a clear sensation of penetrating infiltrated tissue, and then suddenly entering a cavity. Aspiration drew some arterial blood, with distinct pus flakes in greater quantity. The lung was incised with the cautery, carefully

following the needle as a guide. On reaching the tip of the needle the cavity was struck and widely opened. It contained coagulated masses of fibrin of various sizes and shapes and of the same foul odor as the sputum had shown for many months. The finger when introduced palpated an irregular cavity with a perpendicularly forward rising and resistant arch, evidently the posterior wall of a distended larger bronchus. Upward the flexed tip of the finger entered a smaller pocket "around the corner." The cavity lay fully  $2\frac{1}{2}$  inches below the surface of the lung. Drainage was established with a split rubber tube. Iodoform and sterile gauze tampons were inserted and loose dressing applied. The patient was in splendid condition after the operation, and had noticed hardly any pain. One week later, the first change of dressing was made. The lung wound now represented a large cylindric hole in the depth of

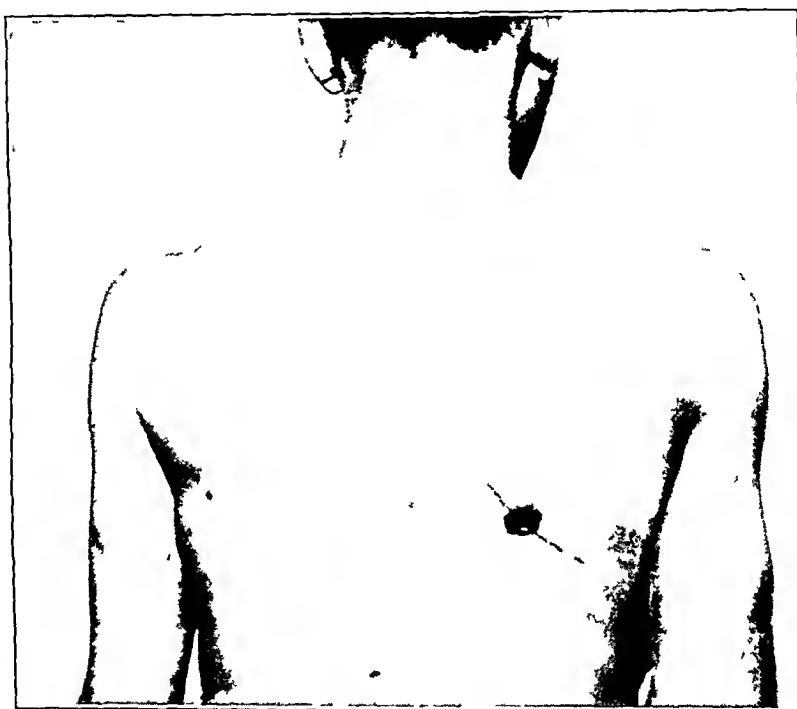


Fig 6 (Case 48) —Nontuberculous bronchiectatic lung abscess of the right lower lobe, due evidently to septic embolism of low virulence, with subsequent localized nonprogressive gangrene. Incision and clearing the cavity from the fibrinous coagulations were accomplished under local anesthesia. Persistent drainage was established for the sake of forcing epithelization of the external opening, successful.

which one large and several smaller opened bronchi were visible. Retamponade was performed. In the course of further after-treatment, care was taken to establish a lung lip fistula. After its definite formation, lasting several months, the rubber drain was removed. In July, 1919, the patient reported that he was in fine trim. He had a slight morning cough, felt in perfect health and was able to work. Today, four years after operation, the artificial pulmonary fistula is still present. Its skin entrance is collapsed. When its lumen is separated, and with the patient's lips closed and nostrils compressed, the

required quantity of air for ordinary respiration can easily be drawn through the fistula. There is no cough, no expectoration and no fetor from the mouth. The patient is at work as a chauffeur and is in splendid physical condition (Fig 5). He is opposed to having the fistula closed at present.

The foregoing experiences, though few in number, appeared significant to me at that time and convinced me, as already stated, that the establishment of a pulmonary lip fistula is a useful operative procedure.



Fig 7 (Case 48)—Wound closed spontaneously and permanently, patient entirely well, coexisting bilateral tuberculous epididymitis, suppurating on one side, was much improved by persistent hyperemic treatment. Today scrotal fistula is closed.

along conservative lines in advanced cases of bronchiectatic lung sup-  
puration, when excision of the lung is either refused by the patient or  
his family, or it is contraindicated.

I decided to try it further, and an opportunity soon presented itself

CASE 48—A man, aged 25, came under my care with a bronchiectatic lung suppuration in the right lower lobe. This time, aspiration had not taken place. The abscess had developed with an attack of fever and had made the patient miserable. Repeated sputum analyses proved the absence of tubercle bacilli. A long stay in the mountains had failed to bring relief. The foul odor of the sputum necessitated his admission to the isolation house at our hospital. The roentgen rays revealed a fluid level in the right lower lobe. The roentgenologist of our hospital, Dr. William H. Stewart, had localized the abscess and advised aspiration, 8 cm. to the right of the spinous process of the dorsal vertebra, which was found, on measuring, to be 20 cm. below the spinous process of the seventh neck vertebra. The aspirating needle found pus at this place. Two days later, under regional and local anesthesia, and with the patient sitting on the operating table, the cavity was found after rib resection, and exposed with the actual cautery. It contained a collection of large and small masses of coagulated fibrin of the same fetid odor as his sputum. Recovery was uninterrupted. I taught his wife how to secure a permanent drainage tube in the wound leading down into the cavity, which was almost 2 inches below the surface of the lung. After the lung lip fistula had formed, which took about six months, and the spontaneous closure of the canal was believed to be impossible, the tube was left out (Fig. 6). Cough and sputum had disappeared long before, and the patient's breath was sweet. He was told to present himself at regular intervals. After some time, he failed to appear and was lost sight of. Through the efforts of our social service nurse at the hospital, he was recently traced, and, on presentation, the fistula was found to be completely healed (Fig. 7). The wound had closed against expectation. There is no cough and no sputum.

An interesting concomitant feature in this case was the presence of a bilateral, chronic tuberculous epididymitis, which I treated with Bier's hyperemia. Still, the lung trouble was surely nontuberculous, as proved by the location of the abscess (lower lobe), the freedom from disease of both apices, the persistent absence of tubercle bacilli and the negative result of the complement fixation test, as well as postoperative developments. It had been my intention to favor the closure of the lung fistula (which here, too, provided for sufficient aeration when the patient was told to close his mouth and compress his nostrils), by extra-pleural thoracoplasty, in order to effect collapse of the affected portion of the lung, aided by external elastic compression, and then freshen the walls of the canal with the actual cautery. The patient's failure to appear frustrated this plan, and Nature did the work alone.

For a complete, immediate cure, lobectomy would have been the operation indicated. To this, the patient was opposed, in view of his having been recently married. His wife, too, refused to consent to a more risky operation.

The case proves that such prolonged ventilation can produce a spontaneous cure after months, without the patient's having to wear a tube or tampon continuously in the wound for drainage, the ventilation being secured by forcing the scar tissue to line a large opening or dip into

a narrower canal and prevent the formation of a bottle-wound as well as the entrance of the bottle's neck closing prematurely. A similar observation was made in Case 45.

A more rapid collection of additional cases in which operation was thus performed became impossible. Since a bronchiectatic clinic had

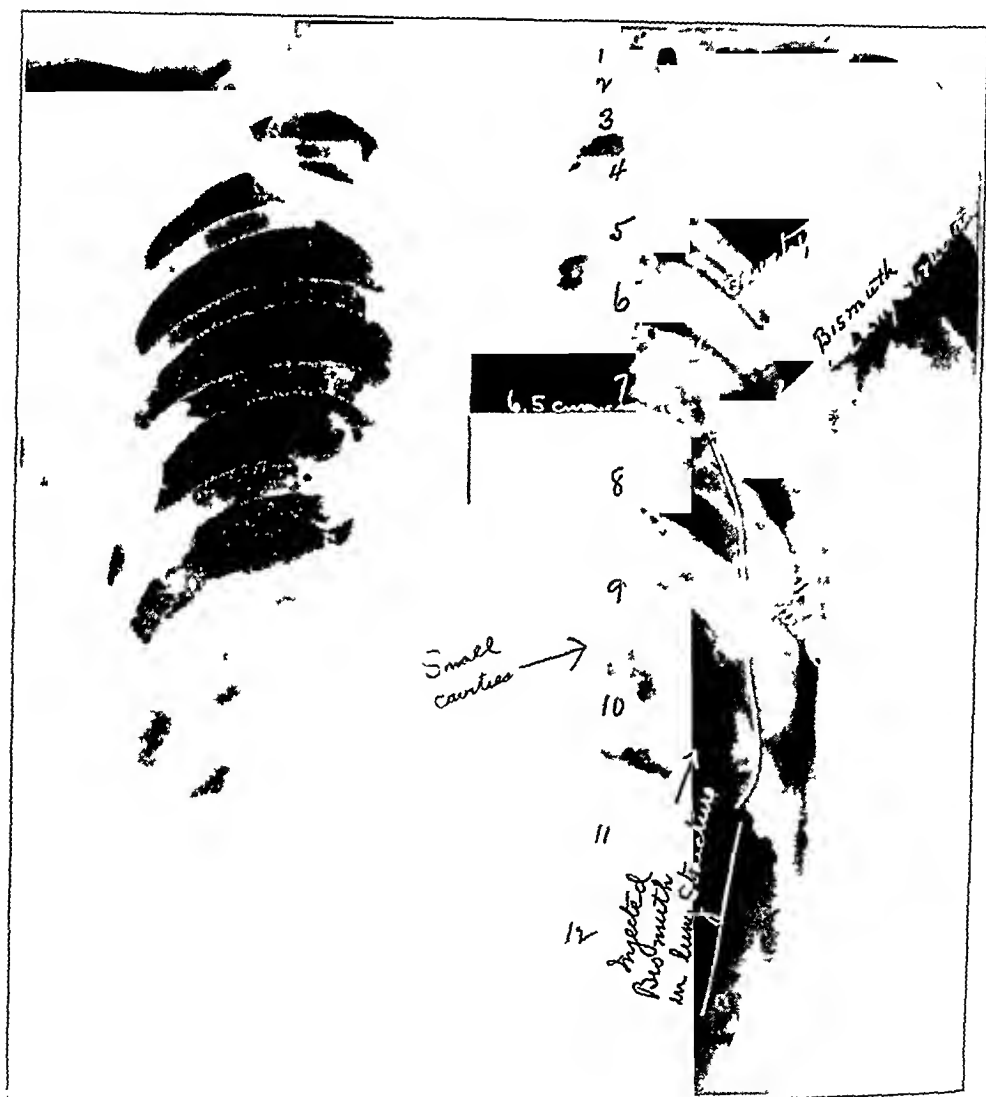


Fig 8 (Case 49) —Roentgenogram taken in the course of the preoperative bronchoscopic treatment of the bronchiectatic lung abscess, which proved to be of hour-glass shape later on. The distinct shadows within the lung parenchyma are due to the injection, for diagnostic and therapeutic purposes, of 5 per cent bismuth oil into the stem bronchus of the lobe, harboring the abscess. The fluid level in the lower portion of the abscess is clearly visible.

been created at our hospital, I considered it my duty, as mentioned above, to turn over suppurating lung cases that had come under my care to the clinic first, in order to find out the possibilities of this

fascinating specialistic treatment and to observe how many of these patients would definitely cross the border line into surgery, and at what period

Of those left to Drs Lynah and Jordan, only one has come back under my care for operation so far

CASE 49—A woman, aged 26, who had always been healthy, developed serious lung suppuration subsequent to tonsillectomy, which was performed at another hospital in October, 1920. She had persistent high fever when the



Fig 9 (Case 49)—Bronchiectatic lung abscess treated by pneumotomy, with prolonged drainage and ventilation, preoperative bronchoscopy and the injection of bismuth oil. Illustration shows the lung lip fistula in the process of its establishment

endoscopic treatment was started. Trials with the direct injection of 5 per cent bismuth oil through a long tube with a movable tip, advised by Dr Lynah, and introduced through the bronchoscope, were made (Fig 8). A bougie cure of the contracted bronchus was resorted to, with direct cauterization of the easily bleeding granulations at this place. Such treatment followed primary, thorough evacuation of the purulent, foul sputum by suction, but the patient did not improve. She developed a larger cavity in the right lower

lobe, proved by clinical and roentgen-ray examination. Unfortunately, bronchoscopic and clinical findings did not completely tally, for endoscopic inspection also proved the middle, perhaps also the upper lobe, to be affected. Dec 14, 1921, under regional and local anesthesia, the cavity in the right lower lobe was exposed and drained with the help of the lower portion of the anterior half of a Schede incision, permitting partial resection of the fourth to the seventh ribs, inclusive. The intercostal soft tissues were also removed. In the axillary and postaxillary lines, the normally colored lung was seen in the various intercostal spaces to move with respiration. There were no adhesions between the lung and pleura in this region, but nearer the spine, the lung appeared darker, almost black, and did not move. Evidently it was adherent



Fig 10 (Case 49)—Both portions of the hour-glass shaped abscess laid wide open after additional rib resection at the time of the second operation, patient still under treatment

Aspiration with a large needle detected pus, and exposure with the actual cautery led to a long, stretched and irregular cavity, which, as in the foregoing cases, contained very foul smelling fibrinous coagulations of various shapes and sizes. These were carefully removed. The immediate addition of the posterior Schede incision and resection of the seventh to fourth rib farther backward, in order to lay the suppurating field in the lung more widely open seemed most desirable. But the patient's condition at the completion of the incision of the abscess forbade it at that time. Drainage of the wound with strips of iodoform gauze and split drainage tubes was established. Cough,

sputum and odor disappeared at once, but the fever persisted, proving the existence of other trouble within the lung. The lung lip fistula formation was sought at once (Fig 9), and thorough persistent respiration through this back door insisted on, while tonic and other medication, later a blood transfusion, kept the reduced patient alive. After six weeks, the fever subsided, and the sputum, which had sometimes still amounted to as much as 350 cc in twenty-four hours, always without odor, commenced to diminish in quantity. April 9, the patient left the hospital, and went to her home. The wound was dressed three times every week and the patient was urged to inhale through the artificial opening as much and as often as possible. She improved and gained in weight. Recently, some increase in temperature and in the quantity of sputum developed, so that the additional posterior incision, with freer opening of the affected area, became necessary. It was done, again under local anesthesia, by my associate at the Lenox Hill Hospital, Dr O C Pickhardt, July 20. After resection of the rib stumps, the seventh to the fourth, inclusive, backward beyond their angle, and after excision of the intercostal soft parts, the lung was split posteriorly upward with the cautery, a grooved director being held within the whole length of the fistulous tract, with comparatively little hemorrhage. When near the upper end of the tract, the director, held by the first assistant, suddenly slipped further upward for quite a distance. On resecting two additional ribs above and splitting the lung further, the exploring finger suddenly entered a cavity in the upper lobe (or in the uppermost portion of the lower lobe) which contained the same masses of coagulated fibrin of very foul odor such as had been found in the first cavity, farther down in the lung, several months before. With drainage by means of split tubes and aseptic tampons, the wound was left wide open (Fig 9). The patient is now on the road to further recovery.

It is hoped that the direct permanent ventilation of the lung lobes—the only operation feasible under the circumstances—will also restore this patient to a fair degree of her former health. It would be a splendid example of our ability, to give help in such complicated cases of lung suppuration by means of a more conservative operation, and restore them gradually as useful members of the community.

#### COMMENT

The five patients, whose histories have just been reported, have been presented before various medical societies in the course of the last few years and their cases discussed. Should I venture to express a conclusion on the basis of the experience gained, I would say that the method promises great improvement, if not an ultimate cure, in certain cases of this type, in stages, and that with a comparatively small rate of mortality. Of course, it must not be forgotten that so long as the canal remains open these patients cannot be considered cured, even if the former lung suppuration has completely subsided. They cannot take a bath, even in the tub, or go in swimming, nor must they ever fall into the water, for instance, while out fishing. Instantaneous death by flooding the lung would be the consequence.



It is true, it might be possible to close the opening with a cork, and, in addition, construct a snugly-fitting and safe suction rubber cap with inflatable neck, as we see it attached to the masks for general anesthesia, to make the fistula air-tight. Still, with the body immersed in water, the life of the patients would depend on the proper working of such a device. The slightest leak, and they would drown instantly.

When the patients have recovered and have been discharged from the hospital, they appear perfectly well. In the case of a severe cold or of undue, and, of course, forbidden exercise (bicycle riding, dancing, playing tennis, etc.) temporary exacerbation may set in later on, with accompanying cough and reappearance of sputum, which is often streaked with blood, also mild fever. However, as stated above, these phenomena are only temporary. The patients soon regain their former greatly improved state and are able to work. Their weight increases, bachelors even marry, and they are so well satisfied with the improvement attained that they refuse the second part of the work planned, the closure of the canal or opening. So far, I have had no chance to attempt closure of the lung fistula, which I think would best be done by means of a circular excision of the skin lip fistula, cauterization of the canal that leads into the lung and collapse of the chest wall by extrapleural thoracoplasty.

In two of the patients just reported this lip fistula has closed spontaneously, both are completely cured.

In conclusion of this report on personal experience in the operative treatment of lung suppuration within the last twelve years, I would emphasize that, as a matter of necessity, the presentation of this subject is necessarily of a somewhat tentative character. The observations made merely demonstrate our efforts to find the operation best suited to the case in hand. I realize fully that we stand but at the very threshold of this important field of thoracic surgery and that the personal views cited above may have to be modified, perhaps considerably, in the course of time.

#### RESUME

1. Bronchoscopy is of great importance in the treatment of acute, subacute and chronic, nonspecific and nonmalignant lung suppuration.

It cannot possibly bring lasting benefit in the typical bronchiectatic case. However, it seems to deserve a permanent place in the specialistic treatment of the bronchiectatic lung abscess. It will likely have its triumphs, if resorted to primarily and promptly, in order to stop completely or reduce the advance of a beginning lung suppuration due to aspiration. The earlier the evacuation of the aspirated infected material from the bronchial tree by means of suction can be carried out, the greater, it seems, will be the chance for lasting improvement and for a definite cure.

2 Of conservative operative procedures, two appear to deserve recommendation (a) ligation of a branch of the pulmonary artery, best combined with extrapleural thoracoplasty at a second stage, in typical bronchiectasis, if lobectomy is contraindicated or refused, (b) the establishment of a temporary or permanent lung lip fistula for prolonged drainage and thorough ventilation in the case of a bronchiectatic lung abscess

3 The typical unilocular lung abscess can heal spontaneously. Otherwise, it is curable by incision and drainage. The difficulty for the operator lies in properly localizing the focus within the chest before operation. Roentgenography promises to assist the surgeon greatly in this respect.

If a preoperative, definite localization of the focus was not possible, then, during the operation, a wider rib resection, with excision of the intercostal soft tissues and inspection of the pulmonal pleura with reference to color and mobility from without, or, as a last resort, incision of the pleura and intrapleural palpation, will, in the majority of cases, reveal where the lung is adherent. Beneath such adhesion, the abscess is usually found. It will be a very rare occurrence in typical lung abscess to find the lung absolutely free from adhesions to the chest wall.

Preoperative aspiration is not advisable. Aspiration with needle and syringe is best done in the course of the operation, when the adherent portion of the lung has been definitely made out.

Incision of the abscess should, if possible, be carried out at one and the same sitting, provided the adherent part of the lung is found, or at a second stage, according to anatomic findings and complications arising in the course of the operative work, after the infiltrated portion of the lung has been stitched in place.

In view of the fact that the lung usually is adherent to the chest wall corresponding to that portion of the lobe which harbors the abscess, it is hoped that a method will be found, roentgenographically, which will show the looked-for lung adhesion in the roentgenogram, and thus obviate the necessity of pleural exploration by the operator's hand.

4 Lobectomy (resection of the lung), as the most radical operation, promises an absolute cure. It should be selected on strict indication and with due respect to the patient's general condition. Its present rate of mortality will no doubt be further reduced in the near future.

#### CONCLUSIONS

The foregoing cases of subacute and chronic lung suppuration are all that have come to me for operation within the last twelve years. It is a rather small and modest showing, small as far as the number of

cases is concerned, and modest as regards the quality of the results obtained. However, as all have been observed and treated by one and the same man, their histories, operations, after-treatment and results may contribute, it is hoped, to some slight extent, to the evolution of this chapter of thoracic surgery.

On analyzing the quantity and quality of the material presented, it must be remembered that twelve years ago thoracic surgery was a rather new field, that the number of colleagues who recognized this addition to the chapter of border-line cases was small in the beginning, that some of those who at first had enthusiastically referred their chronically ailing patients with thoracic diseases to the surgeon were perhaps sometimes disappointed in not seeing, at once and more regularly, positive results, and then hesitated in advising operation to patients similarly afflicted, and, further, that many of the most enlightened soon had to enter military service.

Besides, thoracic cases are scarce as compared with abdominal cases, and at the Lenox Hill Hospital of New York City the division of service according to the type of disease (thoracic, abdominal, urinary, extremities, etc.) could not be introduced so far. Every surgeon there is actively engaged in thoracic work, an arrangement which also has its great advantages, since it enables many minds to work on the solution of difficult problems.

A hand was also lent to determining the value of intrabronchial treatment, which naturally contributed to a reduction of the number of cases reaching the surgeon.

Furthermore, regarding admission of patients with advanced cases of consumption for operation, the laws of the New York State Board of Charities forbid the admission of patients with active tubercle bacilli in their sputum to our wards. It will be advisable for the hospital boards, at least in the state of New York, to set aside some small ward, or, if not available, a few small rooms for the operative treatment of these patients.

Although it will perhaps be seen, in the near future at least, that the surgical treatment of thoracic diseases, including cases of patients afflicted with advanced pulmonary tuberculosis, will become specialized, nevertheless, it seems to me, all general hospitals should be prepared to help those in this deplorable state. In every large hospital, I am sure, at least one surgeon will be found who is ready to operate on patients suffering from troubles above the diaphragm. I believe that, in the end, thoracic surgery will develop in such a way that surgeons universally will take it up, and, like abdominal surgery, it will be in the hands of all.

That the quality of end-results of the cases reported above is not better also has, in part at least, its explanation. Twelve years ago, we

were not capable of making a differential diagnosis of the various types of subacute and chronic lung suppuration—each of which has, it seems to me, its special type of surgical interference—as we are able to do, more or less at least, today, and to select the special type of surgical interference called for. Often we were groping in the dark in order to determine what it was best to do in the given case and how to do it. The cases of the patients sent were usually far advanced. Having been recommended to the “surgeon,” almost everyone was submitted to some kind of operation. Operations were consequently performed which we would refuse today, and some patients were submitted to an interference which we would consider not indicated with our present knowledge. But by way of disappointments and subsequent self-scrutiny, by the cooperative work with the bronchoscopist and roentgenologist, and also by observing and analyzing satisfactory and pleasing results, more light was gradually thrown on a field which at first appeared to us rather bewildering and dark. Incidentally a few principles for personal guidance in thoracic work in general were evolved which may perhaps also help others in this arduous, yet so immensely fascinating field (1) to be prepared for the application of differential pressure in every thoracic operation, in order to meet the possible deleterious effects of an operative collapse of the lung, (2) to push local and regional anesthesia to the limit, for the sake of avoiding, as far as possible, aspiration of pus into, and subsequent inflammation of, hitherto nonaffected portions of the lungs, (3) to try to restore physiologic conditions at the completion of the operation, yet take care of the usually occurring postoperative effusion of fluid into the pleural cavity, which calls for complete closure of the chest wound with air-tight drainage.

## PROCEEDINGS

SATURDAY, APRIL 29—MORNING

The meeting was called to order at 9 30 by Dr Willy Meyer, New York, the president, Dr Samuel Robinson, Santa Barbara, Calif, being unable to be present

Dr Nathan W Green, New York, in the absence of Dr Samuel Robinson, read the president's address on "The Present and Future in Thoracic Surgery"

Dr Rudolph Matas, New Orleans, read a paper on "Anterior Median Thoracotomy by Complete Longitudinal Division of the Sternum for Thoracic Decompression"

Dr Hermann Fischer, New York, read a paper on "Surgical Treatment of the Esophagus"

Dr Howard Lilienthal, New York, read a paper on "Posterior Mediastinotomy"

Dr Wyman Whittemore, Boston, read a paper on "Teratoma of the Right Chest Cavity"

Dr Sidney Yankauer, New York, presented "A Radium Needle for the Esophagoscope"

Discussion was opened by Dr Edward W Archibald, Montreal, Can, followed by Drs Leon T LeWald, New York, Franz J Torek, New York, Evarts A Graham, St Louis, Karl Schlaepfer, Baltimore, Robert T Miller, Baltimore, John L Yates, Milwaukee, Carl A Hedblom, Rochester, Minn, Nathan W Green, New York, Willy Meyer, New York, Rudolph Matas, New Orleans, Hermann Fischer, New York, and Howard Lilienthal New York

SATURDAY, APRIL 29—AFTERNOON

Drs Leon T LeWald and Nathan W Green, New York, read a paper on "The Differential Diagnosis Between Tuberculosis and Lung Abscess"

Dr A L Lockwood, Toronto, Ont, read a paper on "Lung Abscess"

Dr Evarts A Graham, St Louis, read a paper on "The Surgical Treatment of Bronchiectasis"

Dr G J Heuer, Cincinnati, and P M MacCready, Baltimore, read a paper on "Lung Abscess"

Dr Willis S Lemon, Rochester, Minn, read a paper on "The Interrelationship and End-Results of Chronic Suppurative Diseases of the Lungs"

Dr Karl Schlaepfer, Baltimore, read a paper on "Fibrosis of the Lung Following Ligation of the Pulmonary Artery, Combined with Phrenicotomy and with Partial Occlusion of the Pulmonary Veins"

Dr Willy Meyer, New York, read a paper on "Observations on Lung Suppuration and Its Treatment A Brief Review of Personal Experiences and Clinical Impressions Obtained Within the Last Twelve Years"

No discussion

# LIST OF MEMBERS OF THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

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Dr Carroll W Allen	509 Macheca Building, New Orleans
Dr Edward W Archibald	52 Westmount Boulevard, Montreal
Dr Hugh Auchincloss	800 Park Avenue, New York
Dr Edward R Baldwin	6 Church Street, Saranac Lake, N Y
Dr Lewellys F Barker	1035 North Calvert Street, Baltimore
Dr Emil Beck	2632 Lake View Avenue, Chicago
Dr William Branower	1815 Seventh Avenue, New York
Dr Harlow Brooks	47 West Ninth Street, New York
Dr Lawrason Brown	104 Main Street, Saranac Lake, N Y
Dr Harold Brunn	350 Post Street, San Francisco
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Dr Ethan F Butler	Robert Parker Hospital, Sayre, Pa
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Dr Carl Eggers	850 Park Avenue, New York
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Dr Charles A Elsberg	64 East Fifty-Eighth Street, New York
Dr Hermann Fischer	73 East Eightieth Street, New York
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Dr Conrad Georg, Jr	Nickel's Arcade, Ann Arbor, Mich
Dr Evarts A Graham	Washington University Medical School, St Louis
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Dr John A Hartwell	27 East Sixty-Third Street, New York
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Dr James M Hitzrot	126 East Thirty-Seventh Street New York
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Dr James H Kenyon	57 West Fifty-Eighth Street, New York
Dr Adrian V S Lambert	168 East Seventy-First Street, New York
Dr Willis S Lemon	Mayo Clinic, Rochester, Minn
Dr William Lerche	Lowry Building, St Paul
Dr Leon T LeWald	114 East Fifty-Fourth Street, New York

Dr Howard Lilienthal	52 East Eighty-Second Street, New York
Dr A L Lockwood	164 Bloor Street East, Toronto
Dr Howard A Lothrop	101 Beacon Street, Boston
Dr Urban Maes	1671 Octavia Street, New Orleans
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Dr Frank C Mann	Mayo Clinic, Rochester, Minn
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Dr Rudolph Matas	2255 St Charles Avenue, New Orleans
Dr E S McSweeney	132 East Thirty-Sixth Street, New York
Dr Willy Meyer	700 Madison Avenue, New York
Dr James A Miller	379 Park Avenue, New York
Dr Robert T Miller	Johns Hopkins Hospital, Baltimore
Dr James F Mitchell	1344 Nineteenth Street, Washington, D C
Dr George P Muller	1930 Spruce Street, Philadelphia
Dr C D Parfitt	Calydor Sanatorium, on Lake Muskoka, Gravenhurst, Ontario, Can
Dr F W Parham	3513 Prytania Street, New Orleans
Dr Charles H Peck	30 West Fiftieth Street, New York
Dr Henry S Plummer	Mayo Clinic, Rochester, Minn
Dr E H Pool	107 East Sixtieth Street, New York
Dr Walter L Rathbun	Stony Wold Sanatorium, Lake KUSHUQUA, Franklin County, N Y
Dr Martin Rehling	209 East Sixty-First Street, New York
Dr B Merrill Ricketts	Fourth Avenue and Broadway, Cincinnati
Dr Samuel Robinson	420 San Marcos Building, San Barbara, Calif
Dr Francis A C Scrimger	154 Metcalfe Street, Montreal
Dr Charles L Scudder	144 Commonwealth Avenue, Boston
Dr John Smyth	724 Baronne Street, New Orleans
Dr George A Stewart	2427 Madison Avenue, Baltimore
Dr William H Stewart	222 West Seventy-Ninth Street, New York
Dr Franz Torek	1021 Madison Avenue, New York
Dr Martin W Ware	27 East Eighty-First Street, New York
Dr Allen O Whipple	800 Park Avenue, New York
Dr Wyman Whittemore	199 Beacon Street, Boston
Dr Abraham O Wilensky	1200 Madison Avenue, New York
Dr J H Wilms	12 West Seventh Street, Cincinnati
Dr Sidney Yankauer	616 Madison Avenue, New York
Dr John L Yates	512 Wisconsin Street, Milwaukee
* Deceased	

## BENIGN AND MALIGNANT GROWTHS OF THE NASOPHARYNX AND THEIR TREATMENT WITH RADIUM \*

S J CROWE, MD AND JOHN W BAYLOR, MD  
BALTIMORE

The primary object of this article is to report our experiences with the use of radium as a therapeutic agent in nasopharyngeal growths, but we also wish to emphasize the fact that here, as elsewhere in the body, the growth must be recognized during the earliest stages of its development in order to improve materially our present therapeutic results—whether the method of treatment employed is operative, the actual cautery or irradiation

Our results with the radium treatment of lymphosarcoma of the nasopharynx are not good, although this variety of sarcoma disappears locally after irradiation more rapidly than does any other type of tumor with which we are familiar. One possible explanation for this unsatisfactory clinical result is that the earliest symptoms of lymphosarcoma in the nasopharynx are difficulty in breathing through the nose and eustachian tube obstruction, and that these symptoms are usually treated without recognition of the underlying cause until the growth has become diffused throughout the body. We believe that it would be a wise precaution to treat with radium every adult patient that has a localized hypertrophy of the lymphoid tissue limited to the nasopharynx, rather than to remove this hypertrophied tissue with a curet (Case 1). If it were possible to make a definite differential diagnosis between lymphosarcoma and benign hypertrophy from the microscopic appearance of a small fragment of the growth, the excision of a piece for diagnosis might be justifiable, but, unfortunately, a differential diagnosis is often not possible unless the section includes a large portion of the tumor.

When a localized, hard, submucous swelling is discovered in the nasopharynx, or a circumscribed lesion is seen on the mucous membrane that suggests an early carcinoma, thorough surgical extirpation, without preliminary excision for microscopic diagnosis, is the method most likely to result in a cure. In the later stages of carcinoma of the naso-

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\* From the Department of Surgery, Johns Hopkins Hospital



pharynx, surgical removal is hopeless, and although irradiation will greatly ameliorate the symptoms and will occasionally remove the local growth, a cure is rarely possible on account of the metastases

The tumors that arise in the posterior half of the nasal cavities and in the nasopharynx are particularly suitable for the study of radium as a therapeutic agent. The malignant growths that arise in these areas are as a rule recognized so late that complete operative removal is not possible, and many of the benign growths are so vascular that removal would necessitate an extensive and deforming operation. It is in this type of benign tumor that we have had the best results with radium, but the disappearance or marked decrease in size of the local growth in many of the malignant tumors has led us to believe that thorough irradiation at an early stage of their development would produce more favorable results.

When a malignant growth is accessible and can be completely removed without endangering the patient's life, we do not believe it advisable to jeopardize the chances of recovery by first trying radium or roentgen-ray therapy, but in many of the cases that we are reporting the growth was so extensive that it seemed justifiable to employ radium alone.

The clinical diagnosis in many of our cases was supplemented by the microscopic study of a small piece of the growth. The classification of the tumor may be incorrect, since it is often impossible to decide from the histologic appearance of a small fragment of tumor whether the growth is a carcinoma or a sarcoma. It is also difficult to classify the various types of sarcoma that occur in the nasopharynx, and, without the clinical findings or a large section of the tumor, it may be impossible to determine whether the growth is an angioma or an angiosarcoma, a round-cell sarcoma or a very cellular fibroma. This is due in part to the fact that only a small fragment of the tumor is removed for diagnosis and this fragment comes from the surface of the growth, but the difficulties of microscopic diagnosis are also increased by the inflammatory reactions that are so common in tumors of the upper air passages.

Clinically, it is not so important to determine whether the growth is a carcinoma, a sarcoma, an angioma or a fibroma. They all tend to invade the accessory nasal sinuses, the orbit and the intracranial cavity, and for surgical therapy one type is as inaccessible as another. It is desirable, however, to know what types of tumor respond most readily to radium, and, for this reason, we have excised bits of tumor in the majority of our cases.

Before discussing the details of our cases we will review briefly the various types of new growth that occur in the nose and nasopharynx, together with the signs and symptoms that lead to their recognition at an early stage of their development.

## NASAL POLYPS

The polyp is the most prevalent type of tumor in the nasal passages Ewing<sup>1</sup> describes it as a pseudoneoplasm of inflammatory origin that is probably always benign, but Heymann<sup>2</sup> reports three cases in which a polyp has become malignant. This is an important point. It is the general consensus of opinion that a nasal polyp itself does not become transformed into a malignant tumor, but that the polyp appears in certain cases as a result of a deep-seated primary malignant growth under the mucous membrane. Infection is the etiologic factor of the nasal polyp in about 95 per cent of the cases, but the possibility of an underlying growth must always be considered. There is at present a patient in the Johns Hopkins Hospital whose case well illustrates this point.

A white girl, aged 16 years, was admitted with an extensive bilateral destruction of the superior maxilla and a large defect in the hard palate. The history dates from an abscessed upper molar tooth, one year previously, and suggests an osteomyelitis. The painless course of the disease and the extensive destruction of bone suggest syphilis. Aside from the defect in the hard palate, the most prominent features on examination were (1) Large myxomatous polyps filled the nasal cavities and nasopharynx. (2) All of the upper teeth were swaying in their sockets, and the roentgenogram revealed destruction of the entire alveolar process on both sides.

The Wassermann reaction of the patient and that of her mother were both negative, and intravenous therapy did not improve the local condition. We have never seen nasal polyps in association with a tertiary lesion in the nose or hard palate. The polyps in this girl were removed on two occasions. There was nothing unusual in their microscopic appearance, and the true nature of the malady was recognized only when a piece of the mucous membrane at the point of attachment of a polyp showed definite carcinoma.

Histologically, there are three types of nasal polyp.<sup>1</sup> (1) The fibroma edematoides simplex is made up of edematous connective tissue and fibroblasts. The epithelial covering may be ciliated, transitional or squamous. There is usually an accumulation of round cells under the surface epithelium and around the blood vessels. The edema is due to an albuminous transudate, with traces of mucin. (2) The adenofibroma edematoides often shows a pronounced hyperplasia of the surface epithelium and a large number of mucous glands, but the microscopic appearance rarely suggests a neoplasm. (3) The fibroma edematoides cysticum may be mistaken for a true myxoma. The clinical course and prognosis, however, are very different in these two

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<sup>1</sup> Ewing James. *Neoplastic Diseases, a Treatise on Tumors*. Ed 2, Philadelphia W. B. Saunders Company, 1922 p. 80.

<sup>2</sup> Heymann P. *Die Gutartigen Geschwulste der Nase*, *Handb. d. Laryngol. u. Rhinol.* 3: 829-830, 1900.

conditions The fibroma edematoides cysticum is a benign polypoid growth and owes its appearance to the occlusion of alveoli and ducts of the mucous glands, while the true myxoma is a tumor that invades bone Either of these conditions may arise in the ethmoidal region The former is due to a primary infection in the accessory nasal sinuses and does not invade, while the latter is a neoplasm that invades the intracranial cavity or orbit

The choanal polyp is a firm cellular tumor that arises from the mucous membrane of the maxillary or sphenoidal sinuses as the result of a low-grade chronic infection This polyp differs from the types mentioned above only in its location and size It grows through the natural orifices of the sinus and extends backward into the nasopharynx Zarniko observed bone formation and marked hyperplasia of epithelium in a choanal polyp Although these choanal polyps may fill up the entire nasopharynx, they do not adhere to the walls of the nasopharynx and soft palate as do the fibromas A careful nasal examination will usually disclose the pedicle of the tumor coming from one of the accessory nasal sinuses If the pedicle is divided, the growth will drop into the mouth Simple division of the pedicle, however, will not prevent a recurrence, the mucous membrane from which the growth arises must be removed

None of the various types of polypoid growths that occur in the nose or nasopharynx has a rich blood supply, and excessive bleeding following the removal of a polyp always suggests that the primary cause may be a malignant growth instead of an infection

Irradiation has but little influence on the size or growth of polypoid or myxomatous tissue We have never implanted either radium or its emanations into a nasal polyp, but we have repeatedly irradiated heavily both intranasally and externally without curing the polypoid condition

H R Lyons<sup>3</sup> of the Mayo Clinic, however, believes that radium may be used to advantage in the treatment of myxomatous nasal polyps He first removes the polyps, together with the mucous membrane from which they arise, and from three to six days later applies radium directly in the wound He uses a 50 mg tube enclosed in a silver capsule and covered with a sterile rubber finger-cot, and leaves it in place for two hours The polyps may recur within a month after the treatment, but on microscopic examination they are found to contain more fibrous tissue than did the original polyps A second operation, followed by a second irradiation will usually result in a cure No burns

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3 Lyons, H R The Use of Radium in the Treatment of Myxomatous Nasal Polyps Preliminary Report, *Am J Roentgenol* 8 407, 1922

were observed in the fourteen cases treated with from 25 to 50 mg of radium for two hours. He finds that radium will not cure the infection of the accessory nasal sinuses, which is the primary cause of the polyps, but, when used in conjunction with operative treatment, it prevents a recurrence of polyps.

#### NASOPHARYNGEAL FIBROMA

The nasopharyngeal fibroma is a tumor that occurs in boys between the age of 10 and 20 years. It is rarely seen in girls. This type of growth is mentioned in the writings of Hippocrates, who describe an operative method for its removal.

The tumor is benign in the sense that it does not metastasize, but, clinically, it is very different from the other benign tumors of the nasopharynx. It is composed of fibrous tissue with large cavernous blood spaces, especially prominent near the periphery. It grows by extension and invades the orbit, the accessory nasal sinuses, the pterygoid or temporal fossa, or the intracranial cavity. It is characteristic of this tumor that as it grows it becomes attached to the soft parts with which it comes in contact, and thus derives an additional blood supply. This characteristic renders surgical removal very hazardous, often a large fibroma is found to have many points of attachment, and the arteries that enter it may be as large as the external carotid. Mikulicz,<sup>4</sup> in 1899, gave the details of as many as twenty different methods of treatment, including the injection of chemicals, electrolysis, the use of snares and the various methods of surgical removal. The inaccessibility of the tumor and the difficulty in the control of hemorrhage are responsible for the high operative mortality and incomplete removal of the growth irrespective of the method employed.<sup>5</sup>

It is also characteristic of these tumors that they often cease to grow and gradually disappear after the age of 25, just as a fibroma of the uterus may disappear after the menopause. The growth originates from the fibrocartilage of the upper cervical vertebrae, basilar process of the occipital bone, or the internal lamina of the pterygoid process. Bensch,<sup>6</sup> in 1878, pointed out that these growths tend to disappear at the age when the sphenoid and the basilar processes of the occipital bones become united, and ossification of the cervical vertebrae is completed.

Histologically, a fibroma of the nasopharynx may be mistaken for a sarcoma. This is due to the fact that areas of embryonic connective

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<sup>4</sup> Mikulicz, J. Neubildungen des Rachen u. des Nasenrachenraumes, *Handb. d. Laryngol. u. Rhinol.* 2: 411-421, 1899.

<sup>5</sup> Hellat, P. Die sogenannten fibrosen Nasenrachenpolypen, Ort u. Art ihrer Insertion u. ihre Behandlung, *Arch. f. Laryngol. u. Rhinol.* 25: 329-344, 1911.

<sup>6</sup> Bensch, quoted by Ewing, Footnote 1.

tissue are always present, and, if only a small bit of the growth is excised, the microscopic appearance may be very misleading

The most important clinical symptom is bleeding. One of our patients has had numerous spontaneous hemorrhages, with a loss of blood varying from 500 to 1,000 c c on each occasion. Removal of a small piece of growth for microscopic examination in one case was followed by such severe bleeding that transfusion was necessary.

Conservative treatment is particularly indicated in this type of growth. Although our experience has been limited to four cases, two

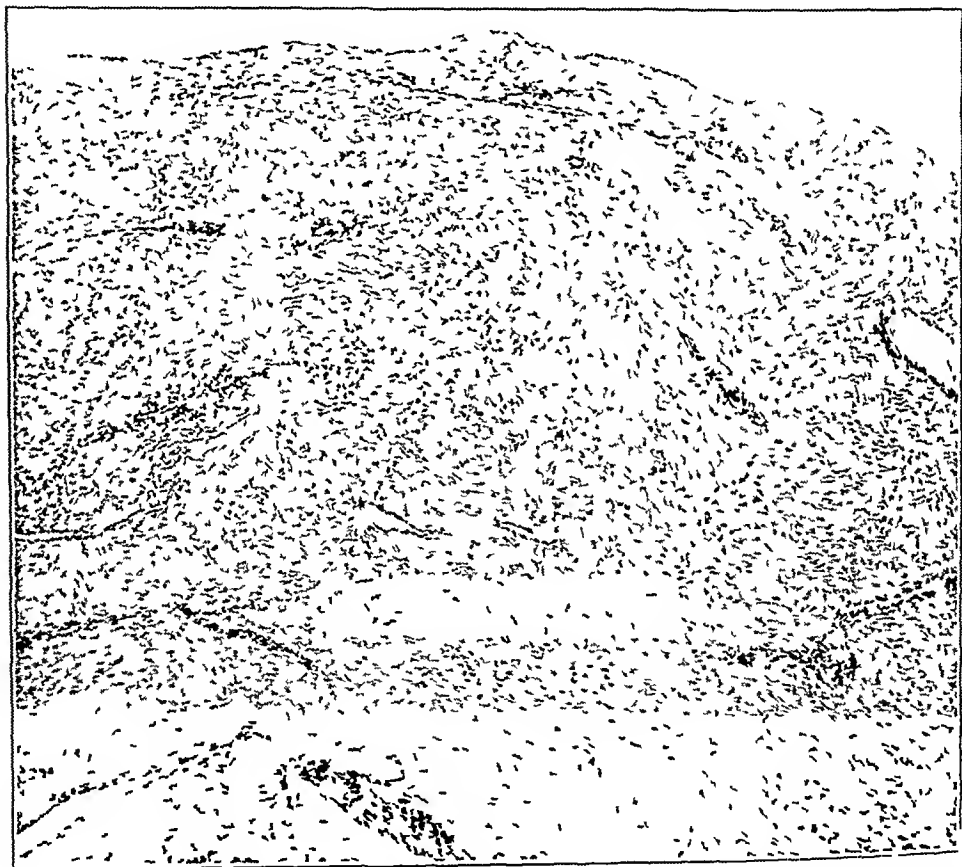


Fig 1—Fibroma of the nasopharynx in a youth, aged 20, treated by heavy irradiation followed by excision of the remainder of the growth, well three years later

of these patients are well, and the other two are improving. The treatment has consisted of a combination of implantation of emanations, intranasal and external irradiation, and partial removal by operative methods. The details of the clinical history and treatment are given in Cases 1 to 4, inclusive. The microscopic appearance of a fibroma of the nasopharynx is shown in Figures 1 and 2. The growth in Figure 1 was cured with radium, while that shown in Figure 2 was cured by operation.

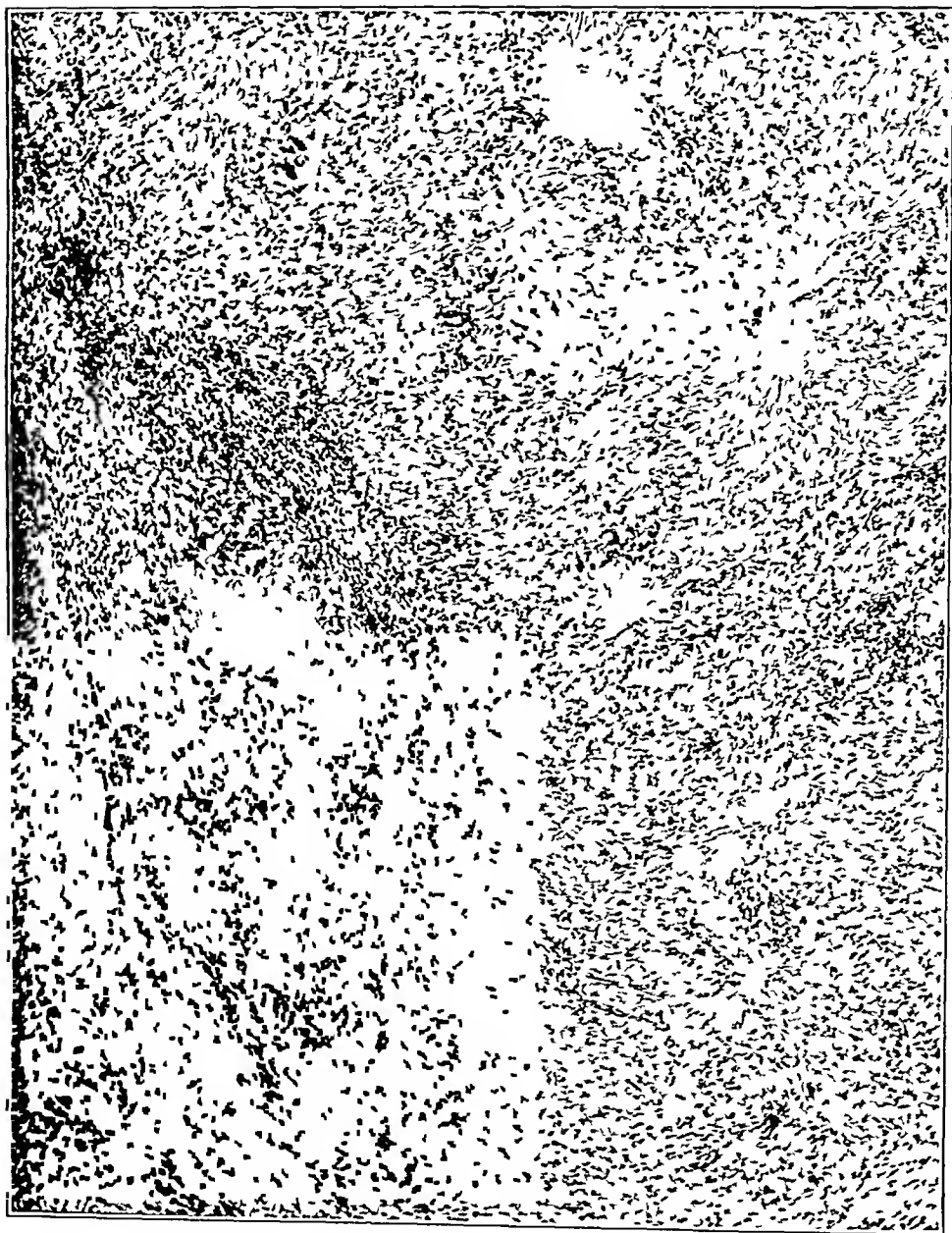


Fig 2—Fibroma of the nasopharynx in a man, aged 26, with a history of frequent hemorrhages, nasal obstruction and impaired hearing for four years, operative removal, no radium, well thirteen years later

## ANGIOMA

Angioma originating on the lateral wall of the nasal cavity is not such a rare condition as the textbooks would indicate. The very exhaustive articles by Heymann and Mikulicz in Heymann's *Handbuch für Laryngologie* only mention angioma in order to emphasize the infrequency of its occurrence in the nose and nasopharynx. The articles of Kummel,<sup>7</sup> Marschik<sup>8</sup> and Oppikofer<sup>9</sup> do not mention this type of growth. The discussion of angioma of the nasal cavity in the textbooks of St. Clair Thomson, Wright and Smith and in the last edition of Denker and of Brunings is limited to the bleeding septal polyps and the varicosities of the septum that occur in Kiesselbach's area. We have had seven cases in which an angioma originated on the lateral wall in the posterior half of the nasal cavity and secondarily invaded the nasopharynx, and one case of a circumscribed submucous angioma, the size of a walnut, that originated and remained localized in the nasopharynx. The histologic appearance of the growth in six of these cases is that of a simple cavernous angioma, while in two cases, the microscopic appearance suggests an angiosarcoma. The clinical history and the absence of metastases to glands, involvement of cranial nerves, invasion of orbit or intracranial cavity justifies their classification as angioma. It should be emphasized again that the histologic appearance of a small fragment of nasal and nasopharyngeal growth does not justify an absolute diagnosis as to the nature of the growth or a final opinion as to the prognosis.

It is noteworthy that in this group of eight cases the first symptom of the growth appeared between the age of 16 and 28 years, the average age of onset was 20 years. The first symptom in every case was nasal obstruction.<sup>10</sup> In three cases tinnitus and impairment of

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7 Kummel, W. Die Bosartigen Geschwulste der Nase, *Handb. d. Laryngol. u. Rhinol.* **3** 874, 1900.

8 Marschik, H. Die Pathologie u. Diagnostik d. malignen Geschwulste der Nase und des Nasenrachenraumes mit Ausschluss der Nasenrachenfibrome, *Beitr. z. Anat., Physiol. Path. u. Therap. d. Ohres* [etc.] **7** 327-378, 1913-1914.

9 Oppikofer, E. Ueber d. primären malignen Geschwulste d. Nasenrachenraumes, *Arch. f. Laryngol. u. Rhinol.* **27** 526-564, 1913.

10 The clinical history regarding nasal obstruction may be misleading in one respect. We have often seen a growth located in the posterior half of the nasal cavity on one side that pushed the septum over until it occluded the opposite side and caused bilateral nasal obstruction. We have seen this with benign growths—such as the fibroma and angioma, and in rapidly growing sarcomas. The carcinomas, on the other hand, rarely reach a size sufficient to push over the septum. They either ulcerate as rapidly as they grow or invade the septum and destroy it. Carcinoma involving the nasopharynx rarely reaches a size sufficient to give rise to obstruction to breathing as an early symptom.

hearing in one or both ears appeared at the same time, or soon after the nasal obstruction was noted. Pain across the bridge of the nose was present in one case, in the remaining seven, the growth caused no pain.

The duration of symptoms varied from two years to ten years before the patient came under our observation, the average was four years. In one case, a large cavernous angioma occupying the entire nasopharynx and obstructing both eustachian tubes had given rise to no symptoms until two weeks before admission, although the growth must have been present for several months.

Severe and frequent hemorrhages from the nose were a prominent feature in five of the eight cases in this group. It is of interest to note that four of the patients had had before admission one or more nasal operations in which a portion of the growth was removed. It is our impression that as a direct result of a partial removal the growth becomes infected and ulcerated, and thus endangers the patient's life from hemorrhage. For this reason, it is probably deleterious to the best interest of the patient to remove a piece of the growth for microscopic examination, and it is certainly not advisable to attempt the removal of the large nasal growths of this type through the nose. The fact that a piece of the growth had been removed was undoubtedly responsible for the frequent and severe hemorrhages in four of the five cases that presented this symptom.

There was unilateral exophthalmos in one case, but in none of the remaining seven cases was there any evidence of involvement of the orbit, intracranial cavity or any of the cranial nerves.

We have been unable to find any statistics of the complications or end-results of operative removal of large hemangiomas located in the posterior part of the nasal cavities or nasopharynx, but our experiences in one case (Case 6) convinced us that surgical extirpation of a growth of this character is an extremely hazardous procedure.

An abstract of the history of two of our cases with extensive nasal angioma will serve to illustrate the advantages and disadvantages of surgical treatment as compared with radium treatment.

CASE 6—A white man, aged 33, was admitted to the Johns Hopkins Hospital in September, 1913, complaining of complete nasal obstruction and epileptic attacks. The first symptom, nasal obstruction, was noticed in 1903. Headache was first noticed during the latter part of 1912. He had his first general convulsive seizure in June, 1913, and, two months later, he had two similar attacks. These attacks were not focal and were not preceded by an aura.

An attempt was made to remove the growth through the nose in 1905. This operation was accompanied by such profuse bleeding that only a small fragment of growth was removed. The operation, however, was probably responsible for the fact that during the next eight years he had frequent and severe hemorrhages from the nose. During the two and one-half years follow-



ing the nasal operation, the patient said that he had received about 200 mg hours of irradiation, but the amount of radium used or the method of application is not stated. This treatment was apparently of some value, for in 1908 his general condition began to improve and the nasal hemorrhages became less frequent.

In 1912-1913, however, the growth was evidently increasing in size, as evidenced by the obstruction to breathing, headaches and epileptic seizures. We, therefore, attempted to remove the growth by surgical operation. Under ether anesthesia, an approach was made through the left antrum. The control of hemorrhage was very difficult on account of the many large vessels that channeled the neighboring bony structures in the roof of the nose and entered the tumor at numerous points. It was impossible to clamp these vessels, and the use of bone wax was of little value on account of their size. After removal of the naso-antral wall and freeing the nasal portion of the growth, the operation was discontinued on account of the excessive bleeding. No attempt was made to remove the growth in the posterior part of the nasal cavity and the nasopharynx. It was necessary to pack the wound with gauze in order to control the bleeding. The infection of the accessory nasal sinuses and of the entire wound necessitated removal of the packs at frequent intervals, and during the five weeks following the operation there were numerous hemorrhages. The hemoglobin on the day of the operation was 92 per cent, and one month later had fallen to 29 per cent, with nucleated red cells in the circulation. The wound gradually closed, however, and, when the patient was discharged on the seventieth day after the operation, the blood count was 4,200,000 red cells, 6,200 white cells and 80 per cent hemoglobin.

A letter from this patient in 1920, seven years after the operation, states that he has had no symptoms of epilepsy and no hemorrhages since leaving the hospital. The nasal obstruction gradually disappeared, and, for several years, he has been well.

It is not an uncommon experience in the surgical treatment of blood vessel tumors in any portion of the body to see the growth gradually regress and finally disappear after a partial extirpation. This is thought to be due to the fact that the portion removed is the primary point of origin or "nucleus" of the growth.

CASE 9—A white boy, aged 18, was admitted to the Johns Hopkins Hospital in March, 1918, with a growth involving the left side of the nose and the entire nasopharynx, which had caused complete nasal obstruction for two years. There was some doubt from the histologic examination of the small piece of tumor removed from the nose as to whether the growth in this case was a simple cavernous angioma or an angiosarcoma. The important point is that this was an inoperable tumor on account of its location, size and vascularity, and that radium treatment has resulted in a disappearance of the tumor.

The first symptom of the growth in this case was difficulty in breathing through the left side of the nose. As the tumor increased in size, the nasopharynx became involved, and the nasal septum was pushed over until the right side of the nose became obstructed. Examination revealed that the growth had eroded the hard palate on the left and was appearing in the roof of the mouth. It is of interest in this connection to note that there is no history of pain. A piece of the growth was removed through the nose on two occasions, and each time the bleeding was profuse and difficult to control.

The general physical examination was negative, with the exception of a well compensated mitral lesion and a secondary anemia. There was no evidence of metastases to the glands of the neck, and the spleen was not enlarged. The blood Wassermann reaction was negative.

The radium treatment in this case consisted of external and intranasal irradiation and the implantation of one 4 millicurie emanation point in the nasopharyngeal portion of the growth. It is of interest to note that the growth decreased in size, the septum resumed its normal position, and, within a month after the first treatment, the patient was able to breathe through the right side of the nose for the first time in a year. Six months later, breathing was reestablished through both sides of the nose. The last examination, three and one-half years after the first radium treatment, disclosed no gross evidence of growth in the nose, nasopharynx or hard palate. The area in which the bone was destroyed in the hard palate healed without secondary infection.

### SARCOMA

In selecting the material for this report, we have included only those cases in which the growth involved the nasopharynx. The cases with tumors limited to the nasal cavity or to the accessory nasal sinuses may be described in a subsequent publication. The primary point of origin is difficult to determine, but in eight of our twenty-six cases of sarcoma the history of involvement of the eustachian tube as one of the earliest symptoms suggests that the growth arose in the nasopharynx. In fourteen cases, however, nasal obstruction was an early symptom and suggests nasal origin. The statistics of Gurlt<sup>11</sup> indicate that sarcoma of the nasal cavity is four times as frequent as carcinoma. Mikulicz, in 1900, referred to the difficulty of recognizing the true nature of a nasal or nasopharyngeal growth by the histologic study of a small fragment, and suggested that many of the cases reported as sarcomas are probably very cellular or infected fibromas. Although metastasis to the cervical lymph glands may be the earliest symptom of a malignant growth in the nasopharynx it not infrequently happens that an ulcerated benign growth or a granuloma in this area is also associated with an early and pronounced enlargement of the neighboring glands. Marschik, in 1914, collected 853 cases of malignant tumor of the nose and of the accessory nasal sinuses. He finds that sarcoma is the most frequent type of malignant tumor in the nose, and that it tends to invade the sinuses secondarily, while the carcinoma arises most commonly within the sinuses and grows into the nose or the intracranial cavity. He also finds that the round cell sarcoma is frequent in the nasopharynx, but is rare in the nose or sinuses.

Marschik refers to the great variation in the histologic appearance of the nasopharyngeal fibroma, and to its similarity to sarcoma.

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<sup>11</sup> Gurlt, E. Beiträge zur chirurgischen Statistik. I. Zur Statistik der Geschwülste. Arch. f. klin. Chir. 25: 421-467, 1880.

Mikulicz, in 1900, and more recently, Oppikofer directed attention to the fact that the microscopic diagnosis of a nasal or a nasopharyngeal tumor may be very misleading, and that every case must be thoroughly studied before a correct diagnosis can be made or an opinion ventured as to the outcome. Mikulicz cites as an illustration a patient with a granulation tissue tumor of the nose who was subjected to an extensive operation for sarcoma because the diagnosis was based solely on the inspection of the local condition and on the microscopic appearance of a fragment of the growth.

In the nose, especially, there is often an inflammatory zone around an early carcinoma that may cause confusion in the histologic recognition of the true condition. Oppikofer refers to the case of a man, 60 years of age, with a nasal tumor. The location, size and appearance of the growth, the age of the patient, and the symptoms all suggested a cancer, but it was necessary to remove three separate pieces before the clinical diagnosis was confirmed. The first piece removed resembled a fibroma with round-cell infiltration, the second piece was diagnosed as a round-cell sarcoma, the third piece, removed from a point near the attachment of the tumor, showed an adenocarcinoma.

Two mistakes are so frequently made by nose and throat specialists that they deserve special mention.

1 The mistake is made of removing a small piece of a nasal or nasopharyngeal tumor and accepting the microscopic report of the pathologist as the true diagnosis of the clinical condition, without taking into consideration the clinical data and the results of statistical studies regarding the age and sex incidence of the various types of new growths in the nose. For example, a vascular, cellular fibroma is the common tumor of the nasopharynx in males from 10 to 20 years of age. It is rare in females at any age. The lymphosarcoma, in adults, is a common tumor of the nasopharynx but rarely occurs as a primary growth in the nose. The spindle-cell and the fibrosarcoma are the most common of the malignant tumors arising in the nose. According to the statistics of J. A. Watson,<sup>12</sup> Klein,<sup>13</sup> Sonnenschein<sup>14</sup> and Oppikofer,<sup>9</sup> sarcoma of the nasal cavity and of the nasopharynx is almost as frequent after the age of 40 as it is in younger persons. A sarcoma usually forms a larger tumor in the nose than does a carcinoma. This is due

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12 Watson, J. A. Sarcoma of the Nasal Passages. An Inductive Study Based on the Records of 150 Cases, *Am Med* 7 553-556, 1904.

13 Klein, H. Pathologisch-histologische Studie über eine seltene Combination von Sarkom und Carcinom der Nasenhöhle, Würzburg, A. Boegler, 1898, p. 33.

14 Sonnenschein, R. Ein langdauernder Fall von Sarcoma nasi, *Arch f Laryngol u Rhinol* 22 528-539, 1909.

to the fact that carcinomas ulcerate at an early stage. Obstruction to nasal respiration and ear trouble, due to involvement of the eustachian tube, are the earliest symptoms of sarcoma, while pain, due to involvement of some branch of the trigeminus, difficulty in opening the mouth, enlarged glands of the neck and bleeding are early symptoms of carcinoma. Glandular metastases appear late in nasal tumors. A sarcoma of the nose or antrum may persist for months or even years and reach an enormous size without involvement of the cervical lymph glands, while the first evidence of a carcinoma or of a lymphosarcoma of the nasopharynx is often the rapid and painless increase in size of the deep cervical glands at the angles of the jaw. Only fourteen of our twenty-six cases of sarcoma of the nasopharynx have palpably enlarged glands of the neck, while in thirteen of our sixteen cases of carcinoma, metastasis to the neck is a prominent finding. One of our carcinoma patients had an extensive operation on the glands of the neck on two occasions, although the severe pain and the location of the glands should have suggested that the primary growth was in the nasopharynx. In another case, blood stained discharge from the nose and mouth and a tremendous enlargement of the cervical glands were the only symptoms of a primary carcinoma of the nasopharynx. The size of the glands may be noted in Figure 19. The primary growth in this case never reached a size sufficient to cause nasal obstruction or a change in the character of the voice. It is of interest to note that this patient received tuberculin treatment for several months on the assumption that the glands were tuberculous. The true nature of the malady was only recognized when an examination of the nasopharynx revealed a small ulcerated growth, and a gland was removed from the neck for microscopic diagnosis. New<sup>15</sup> has recently published, from the Mayo Clinic, two important papers on the symptoms of nasopharyngeal tumors and the mistakes that are made in the early diagnosis of tumors arising in this area. He reports seventy-nine cases, thirty-four were epitheliomas and thirty-three lymphosarcomas. The symptoms were referable to the eye in twenty-one, to the ear in twenty-nine, to the nose and pharynx in thirty-eight, to the glands of neck in fifty-one, to the gasserian ganglion in four, to the jugular foramen in two, and to the intracranial cavity in eleven cases. It is especially instructive to note that, of these seventy-nine patients, seventy-four had had an operation for the relief of symptoms without recognition of the fact that a primary growth in the nasopharynx was the cause of these symptoms. In twenty-four

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<sup>15</sup> New G B. Syndrome of Malignant Tumors of the Nasopharynx, I A M A 79 10-14 (Jul 1) 1922. The Relation of Nasopharyngeal Malignancy to Other Diagnosis. Minnesota Med 4 419-422 (July) 1921.

patients, the tonsils and adenoids had been removed, in eighteen, the glands of the neck, in twelve, the third molars had been extracted, various intranasal operations had been performed in nineteen, and a mastoid operation had been performed for the relief of pain that was due to the growth and not to infection, in one case

2 The second mistake is that of removing a tumor of any kind from the nose or nasopharynx and discarding the tissue without a gross or microscopic examination. One of our patients, a woman, aged 33, was admitted in October, 1915, with a history of nasal obstruction for four years. "Polypi" had been removed from the nose every two or three months from 1912 to 1915. During the early part of 1915, the operations were necessary every month, and later every week. The tissue removed at the various nasal operations was not saved, and no microscopic examination had ever been made prior to her admission here in October, 1915. The growth proved to be a very cellular angiosarcoma, and death resulted from intracranial invasion. We have had two other patients in whom a lymphosarcoma was not recognized for several months after the appearance of clinical symptoms because the tissue removed from the nasopharynx was discarded without examination.

The result of radium treatment in the various types of sarcoma is given in Cases 5 to 33, inclusive. The point we wish to emphasize now is that every growth removed from the nose and throat should be investigated, grossly and microscopically, but, on the other hand, the diagnosis of such growths should not be based on the microscopic appearance of a small fragment, without taking into consideration all of the clinical and laboratory data that are available.

It is doubtful, indeed, whether the removal of a piece of a tumor for diagnosis is ever a justifiable procedure. We have removed tissue for a microscopic diagnosis in nearly every case included in this report, because we wished to study the reaction of the various types of new growth to radium. It is possible, however, that incomplete operative removal or even the removal of a small fragment, either before or during the irradiation, is responsible for the reappearance of the growth in some distant part of the body. If the growth is a very vascular sarcoma or a true angioma, the deleterious effect of a partial removal is apparent in the increased frequency and severity of the hemorrhages. In the majority of our cases of sarcoma, angioma and fibroma bleeding was not a prominent symptom until a portion of the growth had been removed. After the nasal operation, however, the growth becomes infected, and hemorrhages are severe and frequent. We have seen patients with a benign angioma in the nose who had all of the clinical symptoms of an advanced malignant growth. The history of these

patients is that they have noticed difficulty in breathing through the nose or a feeling of fulness in the ear. They consult a physician who discovers the growth and attempts its removal. After this hemorrhages are frequent. The tumor becomes infected, the nose is filled with a purulent discharge containing saprophytic spirochetes and organisms of all kinds, the glands of the neck become enlarged, and the cachectic condition of the patient is due to the loss of blood, to the local infection and to the digestive disturbances that are secondary to the long continued swallowing of the purulent discharge.

In our series of twenty-seven cases of sarcoma in which the nasopharynx was involved, the tumors are classified as follows: lymphosarcoma, 10 cases; spindle cell sarcoma, 2 cases; myxosarcoma, 3 cases; angiosarcoma, 5 cases; round-cell sarcoma, 3 cases; alveolar sarcoma, 1 case; fibrosarcoma, 1 case; osteosarcoma, 1 case; and no microscopic diagnosis, 1 case.

#### LYMPHOSARCOMA

The earliest symptoms in the ten cases that we have included in the lymphosarcoma group were: (1) disturbance of hearing in four cases due to obstruction of the eustachian tube, (2) difficulty in breathing through the nose in two cases, (3) enlarged glands of the neck in four cases, (4) sore throat for four months in one case. Pain due to involvement of the trigeminus was present in two cases, the second division in one, the second and third divisions in the other. It is worthy of note that, in two cases, the growth appeared within three weeks after the operative removal of the tonsils and adenoids. One of these patients, a girl, aged 2½ years, had a history of frequent colds and of having been a "mouth breather" since infancy. A swelling was noticed in the soft palate and the lateral wall of the pharynx two weeks after the operation. We saw this patient for the first time about a month after the tonsillectomy, and the microscopic appearance of the growth is shown in Figure 8. In the second case, a girl, aged 10½ years, the tonsils and adenoids had been removed because of pain and swelling of the left knee and of the right shoulder, although there was no history of an infection of the upper respiratory tract. The rapid enlargement of the glands at the angle of the jaw on the left was the first indication of the growth. When we first saw this child, four weeks after the tonsillectomy, the soft palate and lateral wall of the pharynx on the left were involved. There were no normal landmarks in the nasopharynx. It is unfortunate that in both of these cases the tonsils and adenoids removed at operation were not saved for microscopic examination.

Detailed data concerning the treatment and results in each of these ten cases are given in the reports of Cases 15 to 24, inclusive.

## ANGIOSARCOMA

The next largest group, angiosarcoma, consists of five cases. The orbit was invaded by the growth in two patients in this group, but these two and a case of lymphosarcoma are the only instances in our entire series of twenty-seven cases of sarcoma in which this complication was present. Frequent and severe nasal hemorrhages were a prominent symptom in three cases. One of these patients, however, had two nasal operations, and the bleeding was possibly due to secondary infection of the tumor. Unilateral nasal obstruction was the earliest symptom in three cases and suggests that the growth originated in the nose and involved the nasopharynx secondarily. Only one of the patients in this group had metastases in the glands of the neck. The eustachian tube was involved in one case.

A detailed report of the symptoms, method of treatment and result in the cases classified as angioma and angiosarcoma is given in the reports of Cases 5 to 14, inclusive.

## MYXOSARCOMA

The myxosarcoma group includes three cases. We have classified these tumors as myxosarcoma because they are clinically malignant, and, although very cellular, the individual cells are widely separated by loose poorly staining interstitial material. Photomicrographs of two of these cases are shown in Figures 10, 11 and 12. Nasal obstruction as an early symptom was present in each of these cases, and suggests that the growth arose in the nose. In one case, the growth involved the antrum and later broke through the hard palate. There were no metastatic glands in the neck, no involvement of the orbit or cranial cavity and no history of bleeding in any of these three cases.

The growth was removed by surgical operation in one case, but the patient died within twenty-four hours with symptoms of shock. The two remaining cases were treated with radium alone.

CASE 27—A boy, aged 16 years, reported that the first symptom was nasal obstruction on the left, one and one-half years before admission. The onset of this symptom followed a severe coryza. The child had never had an illness of any kind, with the exception of measles and whooping cough. On admission, the posterior half of the left nostril and the entire nasopharynx were filled with growth. The nasal septum was pushed to the right, thus occluding the right nostril. The growth had not perforated the septum. From the examination, it seemed probable that the growth had originated in the left middle turbinate or in the mucous membrane just below it.

The radium treatment consisting of 83,000 millicurie hours of gamma radiation was applied externally to both sides of the head at a distance of from 2 to 5 inches, 1,800 millicurie hours of gamma radiation was applied directly to the surface of the growth, and two capillary glass tubes, each containing 5

millicuries of radium emanation, were implanted into the growth in the nasopharynx. This treatment caused a burn that resulted in a perforation of the soft palate, but caused no apparent injury to the brain, hypophysis or the eustachian tubes. There was very little, if any, decrease in the size of the growth during the first year of radium treatment. After this, the tumor began to ulcerate, and two years later had entirely disappeared from the nasal passages and from the nasopharynx. The patient was in good health in 1921 and weighed 126 pounds (57 kg.)

In the remaining case (Case 29) there was an extensive growth that, on admission, involved the antrum and the hard palate. The growth was apparently not affected by the three heavy internal irradiations of 46,500 millicurie hours at a distance of from 5 to 6 inches (12.5 to 13 cm.) that he received during a period of ten weeks. Soon afterward, the growth appeared under the malar arch, and the treatment was discontinued. This patient is dead.

Our experience has shown that myxomatous tissue is very resistant to radium. The benign myxomatous polyp that often appears in the nose in association with a pyogenic infection of the accessory nasal sinuses will not disappear after the surface application of beta or gamma irradiation. We have not implanted capsules of emanation into benign polyps. We mentioned above the experiences of the Mayo Clinic in the treatment of myxomatous nasal polyps with radium. Lyons<sup>3</sup> concludes that radium treatment may stimulate the production of fibrous tissue and thus transform a myxomatous polyp into a fibromyxoma. The more fibrous tissue a polyp contains the less tendency it has to recur after surgical removal. Until we know more concerning the effects of irradiation on the surrounding tissues, such as the retina, vessels of the orbit, optic nerve and base of the brain, it does not seem justifiable to employ radium in anything but the inoperable tumors in this region.

The data in regard to the other types of sarcoma in our series—the duration of the growth, the clinical symptoms and the result of treatment—are given in Cases 25 to 33, inclusive. In our experience, the spindle-cell, round-cell and myxomatous sarcomas are less favorable for radium treatment than are the more vascular types.

#### CANCER

We include in this group sixteen cases that have been observed during the last twelve years. The diagnosis of cancer was confirmed in every case by the histologic examination of a fragment of the growth. Every patient in this group is dead. Six had definite evidence of intracranial invasion, ten had frequent and severe hemorrhages from the mouth or nose or a history of a bloody discharge, thirteen had metastases to the glands of the neck and in nine instances there was



such a marked fixation of the jaw that the patients were unable to take solid food. These are the outstanding clinical symptoms in carcinoma of the nasopharynx, and they differ markedly from the symptoms caused by the sarcomas or any of the benign tumors that involve this region. These symptoms of cancer, however, are the late manifestations of the growth, and, when they are all present, the condition is too far advanced for a cure by any method.

We have carefully gone over the history of each of these sixteen patients in order to tabulate the earliest symptoms of carcinoma of the nasopharynx.

1 It is noteworthy that in two patients a constant discomfort and soreness of the throat were the first symptoms. It is difficult to secure accurate data as to how long the sore throat had been present before the other evidences of a new growth became evident, but certainly an early carcinoma should be considered in the differential diagnosis of the cause of a slight soreness in the nasopharynx and pharynx that persists for several weeks. The other common causes of a persistent sore throat are (1) the secondary and tertiary lesions of syphilis, (2) the tuberculous ulcerations of the pharynx secondary to a pulmonary infection, or (3) the primary tuberculous lesions of the lymphoid tissue in the tonsils or the nasopharynx that do not ulcerate and that can but rarely be recognized until the tissue is removed for microscopic examination or the glands of the neck become involved, (4) infection with Vincent's organisms, and (5) a chronic pyogenic infection of the tonsils and adenoids.

2 In seven patients, the first symptom of the carcinoma in the nasopharynx was impairment of hearing, a feeling of fulness, and later pain and discharge from one ear. These symptoms are due to the fact that the growth originates near the pharyngeal orifice of one of the eustachian tubes. In three of these seven cases, the patient first consulted an otologist on account of a feeling of fulness in one ear or impairment of hearing. In each case, the symptoms were treated from two to seven months, and the primary condition in the nasopharynx was not recognized until the involvement of adjacent nerves, muscles or glands made the diagnosis evident. The failure to recognize these nasopharyngeal growths at an early stage is due to careless and inefficient methods of examination. A reflex cough and an irritable pharynx are often early symptoms of a growth in the posterior part of the nose or nasopharynx, whether the tumor is due to a benign hypertrophy of the posterior end of the turbinates or is malignant. This irritability of the pharynx makes it difficult to use a pharyngeal mirror, and many laryngologists and otologists are either too busy or too impatient to anesthetize the pharynx with cocaine or to inspect the nasopharynx with

an electrically lighted nasopharyngoscope. There is little prospect of ever curing a carcinoma of the nasopharynx with either radium or operation if the growth is not recognized before the adjacent tissues have been invaded.

3 Recognizable metastases to the glands appear late in nasal tumors, while in primary nasopharyngeal growths enlarged glands near the angles of the jaw appear early. In one of the patients in this series, the glands of the neck had been removed on two occasions before the primary growth in the nasopharynx had reached a size sufficient to direct attention to this region. In another patient (Fig 19), the enlarged glands were for several months regarded as evidence of tuberculosis or Hodgkin's disease, and their true nature was not suspected until tissue was excised for diagnosis. The slight but persistent sore throat and the occasional bleeding in this case were, for the period of a year, the only symptoms of the primary nasopharyngeal growth. In a third case, the only symptom for a period of three months was an enlarged gland near the angle of the jaw on the left, and the first indication of a nasopharyngeal lesion was a gradually developing stiffness of the jaw and inability to open the mouth. A possible explanation of the rapid enlargement of the metastatic glands in the neck, while the primary nasopharyngeal cancer does not become large enough to cause obstruction to breathing, is the tendency of the carcinomas of the mucous membrane in this region to ulcerate as rapidly as they grow. The sarcomas of the nasopharynx, on the other hand, usually grow rapidly, do not ulcerate unless injured and cause obstruction to breathing at an early stage.

Dr G B New,<sup>16</sup> in a recent review of forty-six cases of malignant tumor of the nasopharynx observed at the Mayo Clinic, found that in twenty-two of the forty-six cases there were no symptoms referable to the nose or throat. On account of the variability of the symptoms, some of the patients had been subjected to various operations and treatments, such as the extraction of teeth, treatment for syphilis, removal of the glands of the neck, paracentesis, intranasal operations, tonsillectomy and operation for pituitary tumor. The failure to recognize the primary growth in the nasopharynx was due to the fact that this region was never examined.

In Cases 34 to 49 inclusive, the symptoms and the objective findings in each of our sixteen cases of carcinoma of the nasopharynx are recorded. Many of these symptoms, however, are the late manifestations of the growth, and, when they are present, there is little hope of effecting a cure with any methods of treatment.

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16 New G B Footnote 16 second reference

## COMMENT

There is an extensive literature on the subject of nasal and nasopharyngeal growths,<sup>17</sup> but very little has been written in regard to their treatment with radium. In this paper we have said but little about the detailed technic of irradiation. Radium as a therapeutic agent is more dangerous than the roentgen ray, and should be employed only by those who, in addition to their medical education, are thoroughly familiar with physics and higher mathematics. A large clinical experience and a careful correlation of dosage, method of application and result, in the various types of new growths, are essential for the training of a radiologist. For example, it is conceivable that a physician or surgeon, untrained in biophysics, might advise a patient with a localized lymphosarcoma in the throat to have prophylactic irradiation of the mediastinum, abdomen and the glands in the axilla and groin, but a physicist would recognize immediately that such a plan of treatment would result in profound changes in the blood and probably hasten the death of the patient.

Radium treatments in all of our cases have been planned and executed by Dr. Curtis F. Burnam of the Howard A. Kelly Hospital in Baltimore. The amount of radium used and the method of application in our cases are given in the tables, but we do not feel competent to discuss the details of these treatments.

We have mentioned above the difficulties of classifying these nasal and nasopharyngeal tumors by the microscopic examination of a small fragment of the growth. It is sometimes impossible to differentiate a sarcoma from a carcinoma, an angioma from an angiosarcoma, or a cellular fibroma from a sarcoma. For this reason, we have reported our cases at length, giving the age, sex, duration of symptoms, clinical findings, treatment and end-result. The diagnosis of the type of tumor may be incorrect in several instances, but we have attempted to present these cases from a biologic point of view, and believe that the accumulation of sufficient data of this kind will be a great aid to the clinician.

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17 The most instructive articles are those of Heymann, Kummel and Mikulicz in Heymann's *Handbuch für Laryngologie*, Harmer and Glas (*Die malignen Tumoren der inneren Nase [Eine klinische histologische Studie]*, *Deutsch. Ztschr. f. Chir.* **79** 433-539, 1907), Marschik, Oppikofer, Berthold Müller (*Zur Pathogenese und Therapie der Nasenrachenfibrome*, *Ztschr. f. Ohrenh.* **70** 145-179, 1914), Pollak (*Ueber die "endotheliale" Geschwulste der Nase und ihrer Nebenhöhlen*, *Arch. f. Laryngol. u. Rhinol.* **25** 383-400, 1911), J. A. Watson, G. B. New, and Schmiegelow (*Einige Beobachtungen hinsichtlich der Wirkung des Radiums auf inoperable maligne Neubildungen im Mund, Rachen und in der Nase*, *Arch. f. Laryngol. u. Rhinol.* **33** 1-18, 1920).

One outstanding result of the radium treatment of these cases is the high percentage of cures in the vascular tumors. In such an inaccessible region as the nasopharynx, the large vascular tumors are not suitable for surgical removal, but if untreated, they not only become infected, ulcerate and bleed profusely, but may destroy the neighboring structures by pressure, and grow into the orbit and intracranial cavity. Clinically, this type of tumor, although it may not metastasize, is as serious in its consequences as a malignant growth. Although these vascular tumors do not disappear so rapidly after irradiation as do some other types, for example, lymphosarcoma, the end-result is much better. A large lymphosarcoma with metastatic glands in the neck may disappear entirely within a few weeks after the first radium treatment, while a hemangioma of the same size may require four or five years to effect a cure. We have at least two patients who had myxosarcoma involving the nose and nasopharynx that are well. The microscopic appearance of this tumor is shown in Figure 10, and, by referring to Cases 27 and 33, it will be seen that tremendous irradiation, extending over a period of several years, has been necessary to effect a cure.

No case of carcinoma of the nasopharynx in this series has been cured, but, in many cases, the symptoms have been ameliorated. In some instances the rapid decrease in size of the primary growth leads us to believe that the unfavorable outcome is due to the fact that these patients do not apply for treatment until metastases have occurred.

It is important for the medical profession to know that tumors in the posterior part of the nose and in the nasopharynx are not uncommon, and that their earliest symptoms may be referable to the ear, the eye, the glands of the neck or to the area of distribution of some branch of the trigeminal nerve. The recent publication of New from the Mayo Clinic is very instructive. During the last six years, he has observed seventy-nine patients with a malignant growth in the nasopharynx, and he states that seventy-four of these patients had had an operation of some kind for the relief of symptoms without recognition of the primary growth in the nasopharynx.

#### REPORT OF CASES

##### FIBROMA OF THE NASOPHARYNX

CASE 1—*History*—A white boy aged 15, was admitted in March, 1920, complaining of inability to breathe through the nose, the onset of which had occurred four years previously. Several pieces of growth had been removed by his home physician, three years previously, but none of this tissue was available for microscopic examination. Frequent and severe hemorrhages had occurred during the previous three years. A swelling had been present on the right side of the face for two years, also tinnitus in the right ear.

*Examination*—The Wassermann reaction was negative. No metastatic glands were discovered in the neck. The growth, which had originated in the nasopharynx, had grown into the right nostril, ethmoidal sinuses and antrum, causing swelling on the right side of the face. There had been no loss in weight. The growth in the nasopharynx was smooth and soft. The hard palate protruded into the mouth.

*Diagnosis*—No tissue was removed on account of the history of severe hemorrhages. The clinical diagnosis was fibroma.

*Treatment*—Intensive irradiation was used, March 4 and Sept 3, 1920, a total of 42,600 mc hours of gamma radiation at a distance of 5 inches being employed over the right side of the face. Eleven millicuries of radium emanation was implanted in the growth in glass capillary tubes.

*Course*—September, 1920, the growth had increased in size, filling the nasopharynx and the right side of the nose. The septum was pushed over to the left, thus occluding the left nostril. The growth was sloughing at the site of implantation of the radium. The glands of the neck were not enlarged.

*CASE 2—History*—A white boy, aged 16, was admitted in October, 1919, complaining of inability to breathe through the nose and bleeding. The adenoids had been removed a year previously, but none of this tissue was available for microscopic examination. Frequent and severe hemorrhages had occurred during the past year. A growth, which had been discovered in both sides of the nose, ten months previously, had been partially removed, followed by a severe hemorrhage. This impaired the hearing in both ears, but the impairment was worse in the left.

*Examination*—The Wassermann reaction was negative. No metastatic glands were discovered in the neck. There was no pain. There was a bloody discharge from the nose. A huge growth was found in the nasopharynx pushing the soft palate forward, causing difficulty in breathing through the mouth at night and complete nasal obstruction. The orbit, intracranial cavity and antrums were not involved.

*Diagnosis*—No tissue was removed on account of the history of a severe hemorrhage. The clinical diagnosis was fibroma.

*Treatment*—Between Oct 25, 1919, and June 23, 1920, the patient received intensive radium treatment from the outside, directly against the tumor in the nasopharynx and by implantation, a total of 40,900 mc hours of gamma radiation was applied over the outside, at a distance of 4 inches. Seven hundred and fifty millicurie hours of gamma radiation was employed against the tumor in the nasopharynx, and  $23\frac{1}{2}$  mc of radium emanation, in glass capillary tubes, containing from 1 to 3 mc each, was implanted into the tumor.

*Course*—November, 1919, there was considerable irritation due to the radium and severe pain. The growth had decreased in size.

December, 1919, the growth was invisible in the mouth, but the nose and nasopharynx were still filled with the growth.

January, 1920, there had been no decrease in the size of the growth during the previous month.

June, 1920, the growth had become smaller, allowing a little breathing through both sides of the nose. The hearing was normal. There were no headaches, no pain or fixation of the jaw. There were no enlarged glands in the neck. A very severe hemorrhage occurred a few days previously.

CASE 3—*History*—A white boy, aged 18, was admitted in June, 1915, complaining of nasal obstruction, but with no headache or bleeding

*Examination*—The Wassermann reaction was negative A large, soft, pink mass had originated in the left side of the nasopharynx and had grown into the nose posteriorly on the left There were no eye or ear symptoms, and the glands in the neck were not enlarged

*Diagnosis*—The clinical diagnosis was fibroma

*Treatment*—Between June 25, 1915, and June 29, 1916, the patient was given five rather intense intranasal irradiation treatments and heavy treatment from the outside, with a total of 1,250 mc hours of gamma radiation An external irradiation, consisting of 1,000 mc hours, was employed at a distance of 2 inches, over the left side of the face

*Course*—December, 1915, the growth was much smaller Breathing was well established in both sides of the nose There was still a small growth in the nasopharynx and in the posterior half of the nose on the left There was no bleeding or ulceration

June, 1916, there was still a small growth, but breathing was good There were no subjective symptoms

March, 1917, the growth had entirely disappeared, and the general health was excellent

CASE 4—*History*—A white man, aged 20, was admitted in January, 1918, complaining of nasal obstruction, with bleeding from the nose and the mouth The adenoids were removed in April, 1917, but no microscopic examination had been made of this tissue A growth had been discovered in the left side of the nose and nasopharynx, two months later A piece was removed and diagnosed as sarcoma

*Examination*—The Wassermann reaction was negative No metastatic glands were found in the neck There were no ear symptoms and no headache The differential blood count was normal The growth occupied the left side of the nasopharynx and the anterior wall of the sphenoidal sinus on the left

*Diagnosis*—The clinical diagnosis was fibroma

*Treatment*—The report of the radium treatment was lost from the history but the amount of irradiation was approximately the same as in Case 3 A portion of the growth in this case was removed, and, on one occasion, 542 mc of radium was applied directly in the wound for eleven minutes

*Course*—May, 1918, there had been no bleeding since the first radium treatment The patient had gained 20 pounds during the previous three months There was a crater-like depression in the region formerly occupied by the growth The area was now covered with a normal appearing mucous membrane

December, 1918, the patient was well, and there was no recurrence

June 1921, the patient was well and there was no recurrence

#### ANGIOMA AND ANGIOSARCOMA OF THE NASOPHARYNX

CASE 5—*History*—A white woman, aged 28, was admitted in May 1913, complaining of tinnitus with an impairment of hearing on both sides, of two weeks' duration

*Examination*—The Wassermann reaction was negative There had been no history of bleeding There were no enlarged glands of the neck A large firm growth occupied the entire nasopharynx obscuring both eustachian tubes with a middle ear type of deafness

*Diagnosis*—The clinical diagnosis was hemangioma (Fig 3)

*Treatment*—The patient received no radium treatment. The growth was removed after splitting the soft palate. About 0.5 cm of the right eustachian orifice was removed with the growth, with no subsequent dilatation of the tube. There was very little bleeding during the operation, and no postoperative bleeding.

*Course*—February, 1921 (nearly eight years after the operation), the patient was perfectly well, and there was no evidence of any recurrence. The voice was normal. The hearing, also, was normal on both sides. The orifices of both eustachian tubes were open, and the orifice of the right tube was of about normal size.

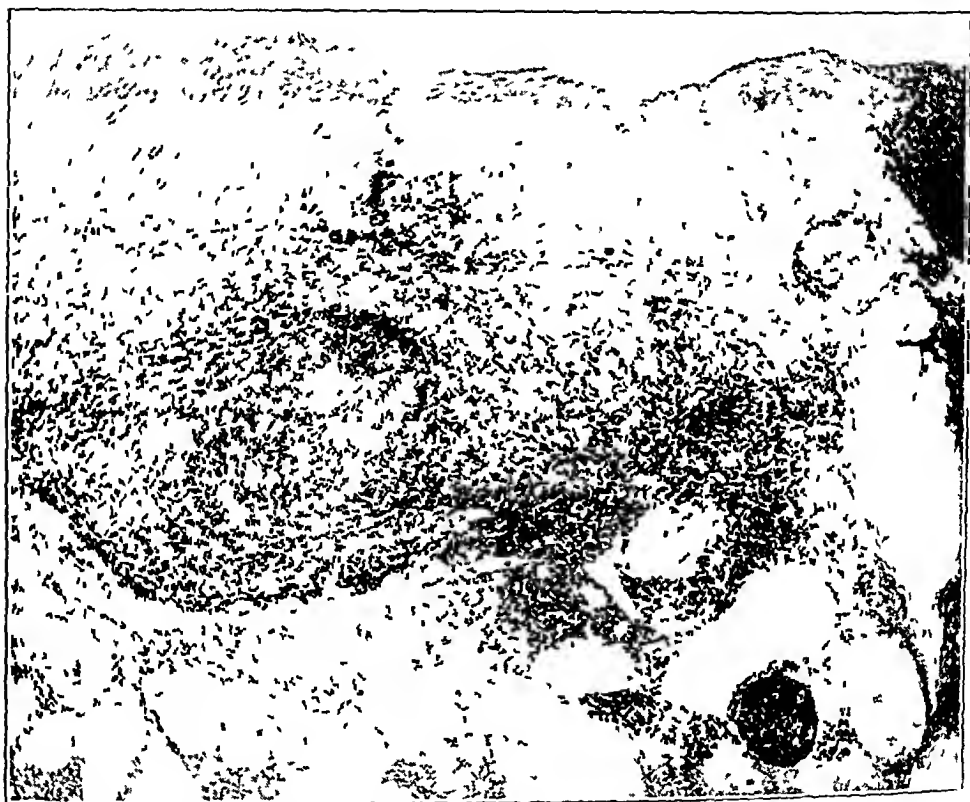


Fig 3—Angioma originating under mucous membrane of nasopharynx in a woman, aged 28, no history of bleeding, operative removal, no radium, well eight years later.

*CASE 6—History*—A white man, aged 33, was admitted in September, 1913, complaining of a nasal obstruction of ten years' duration, epilepsy of four years' duration and frequent and severe nasal hemorrhages. The patient had had numerous nasal operations during the last nine years, which were always followed by severe hemorrhages.

*Examination*—The Wassermann reaction was negative. There were no enlarged glands of the neck and no ear symptoms. A growth arose from the lateral wall of the right nostril, filling the nasopharynx, and was adherent to the septum posteriorly. The neurologic examination was negative. Dr H M Thomas believed that the patient was suffering from epilepsy.

*Diagnosis*—The clinical diagnosis was hemangioma (Fig 5)

*Treatment*—No radium treatment was employed. The patient said that he had received 200 mg hours before admission, which for a time improved his



Fig 4—Angioma occupying the left side of the nose and entire nasopharynx in a man, aged 25 showing the large ulcerated area in contrast to Figure 3. Bleeding was a prominent symptom, radium treatment, patient well four years later.

condition. The growth was removed by operation. An incision was made over the right antrum, but the antrum was not involved. The entire lateral wall of the nose, the mucous membrane of the floor of the nose and the posterior half of the septum were all removed in one piece. The profuse hemorrhage at



operation was controlled by packing. At one time, blood examination revealed erythrocytes, 2,000,000, leukocytes, 6,500, hemoglobin, 29 per cent. Many of the erythrocytes were nucleated. The blood pressure was 72. Blood transfusion was not performed.

*Course*—January, 1921 (nearly eight years after operation). The patient has been perfectly well since leaving the hospital. There has been no recurrence of bleeding, and he breathes normally through both sides of the nose. He has not had an epileptic attack since leaving the hospital.



Fig 5—Angioma involving entire right nostril and nasopharynx in a man, aged 33, history of frequent hemorrhages and epileptic attacks for four years, operative removal, no radium, severe postoperative hemorrhages, hemoglobin rose to 29 per cent, well eight years later, no epileptic attacks since operation.

*CASE 7—History*—A white man, aged 25, was admitted in February, 1917, complaining of a nasal obstruction on the left side, with frequent hemorrhages from the mouth and the nose, of about four years' duration. There had been no headaches and no ear symptoms.

*Examination*—The Wassermann reaction was negative. A growth filled the posterior half of the left nostril and the entire nasopharynx. There were no enlarged glands in the neck. There was a history of nasal operation, three years previously, which was followed by a severe hemorrhage and a rapid

recurrence of the growth. A piece of the growth was removed for microscopic examination, and severe bleeding followed. A roentgen-ray examination of the chest revealed nothing abnormal.

*Diagnosis*—The clinical diagnosis was hemangioma (Fig. 4).

*Treatment*—Between Feb. 27, 1917, and April 16, 1917, the patient had received heavy external irradiations and a mild irradiation in the posterior pharynx. The external treatment consisted of 60,800 mc. hours of gamma radiation, being employed at a distance of 3 inches, and distributed over both sides of the face and both sides of the nose. The intranasopharyngeal treatment consisted of 250 mc. hours of gamma radiation employed directly against the growth in the nasopharynx. In this case also, the hemorrhages from the nose and the mouth stopped after the first irradiation, and never recurred.

*Course*—March, 1917, the patient had markedly improved and could breathe much better. There had been no recent bleeding.

April, the growth had entirely disappeared from the left side of the nose, but there was still a considerable mass of tumor in the nasopharynx.

February, 1921, the patient had free breathing space on both sides and had been working regularly since June, 1917. No bleeding recurred, and there was no evidence of the growth in the nose or nasopharynx.

*CASE 8—History*—A white youth, aged 19, was admitted in January, 1917, complaining of a nasal obstruction on the right, of three months' duration, with severe bleeding from the nose and mouth. He had no headache and no ear symptoms.

*Examination*—The Wassermann reaction was negative. A growth filled the nasopharynx and the posterior part of the nose on the right, pushing the septum over and causing a partial obstruction on the left. There was no evidence of metastases in the neck. The neurologic examination was negative.

*Diagnosis*—The clinical diagnosis was angiosarcoma.

*Treatment*—Between Jan. 26, 1917, and Feb. 18, 1919, the patient had received intensive irradiation, a total of 77,200 mc. hours of gamma radiation being employed at a distance of from 3 to 4 inches, centered over the right side of the face. He had also received 600 mc. hours of gamma radiation applied directly against the growth in the posterior nares. The cessation of the nasal hemorrhages was very striking in this case. Jan. 24, 1917, the hemoglobin was 58 per cent; one month later, it was 78 per cent. During this period, irradiation was the only treatment that the patient received.

*Course*—January, 1917, persistent and severe nausea occurred after the irradiation.

April, 1917, the patient was able to breathe through both sides of the nose, but the growth was still visible in the nose and the nasopharynx. The weight was 140 pounds, which was a gain of 6 pounds during the past month. The general health was excellent.

November, 1918, there was a marked improvement. A small amount of the growth was still attached to the posterior part of the septum, as well as between the posterior end of the middle and inferior turbinate on the right. Both of the eustachian tubes were clear for the first time. There was still a little growth in the left fossa of Rosenmueller.

February, 1919, there was no evidence of metastases, but there remained a small piece of growth in the posterior end of the inferior turbinate region on the right.

January, 1922, the patient wrote that he was in the best of health.

*CASE 9—History*—A white boy, aged 18, was admitted in March, 1918, complaining of a chronic nasal discharge since infancy. There was a history of a nasal operation, eighteen months previously, which was followed by a severe hemorrhage. The entire nasopharynx was filled with a growth which pushed the septum over, causing a complete nasal obstruction on the left.

*Examination*—The Wassermann reaction was negative. The growth apparently had originated in the left side of the nose, and involved the entire nasopharynx. It had eroded through the hard palate on the left, but not through the mucous membrane. No metastatic glands were found. Bleeding had been a prominent symptom. Aside from a secondary anemia, the general physical examination was negative. There was no history of headache or pain.

*Diagnosis*—The clinical diagnosis was hemangioma.

*Treatment*—Between March 30, 1918, and Aug. 9, 1919, the patient received very heavy external irradiations and also moderate internal irradiations. The external irradiations consisted of 66,700 mc hours of gamma radiation employed at a distance of 4 inches, distributed over both sides of the face and neck. The intranasopharyngeal treatment totaled 700 mc hours of gamma radiation. Oct. 15, 1919, one needle point containing 4 mc of radium emanation was implanted in the growth in the nasopharynx.

*Course*—April, 1918, the patient was able to breathe through the right side of the nose, for the first time in a year.

October, 1918, the patient could breathe through both sides of the nose. The growth in the hard palate had not progressed.

January, 1919, the general condition was excellent, and the patient was able to breathe freely through the nose. There were no enlarged glands in the neck.

April, 1919, the growth in the nose was limited to the posterior half of the middle turbinate and the space between this and the inferior turbinate.

October, 1919, the general condition was excellent. The growth still remained in the posterior part of the nose on the left and in the nasopharynx, but there was no obstruction to breathing. There had been no bleeding during the previous year, and no metastatic glands were found.

*CASE 10—History*—A white woman, aged 47, was admitted in April, 1915, complaining of frequent and severe hemorrhages, eighteen months previously, also of a nasal obstruction on the right.

*Examination*—The Wassermann reaction was negative. The adenoids had been removed thirty years previously. The general health had been excellent until the bleeding began, one and one-half years previously. The growth apparently originated from the region of the right middle turbinate, filling the entire nasopharynx. No metastatic glands were found, and the patient had no headache. A roentgen-ray examination of the chest was negative. The nature of the growth was recognized in New York, in March, 1914, and the patient was told that there was no hope for a cure by operation, but the use of radium was suggested.

*Diagnosis*—A microscopic diagnosis proved the growth to be angiosarcoma.

*Treatment*—The patient received intensive irradiation between March 29, 1915, and Oct. 11, 1916, a total of 27,800 mc hours of gamma radiation being employed at a distance of  $2\frac{1}{2}$  inches over the right side of the face. She also received 500 mc hours of gamma radiation directly against the growth in the right nostril. The patient reported regularly, and after Oct. 11, 1916, she

received several other radium treatments over the right side of the neck, which were given to reduce the adenoma of the thyroid, not affecting the condition in the nasopharynx

*Course*—April 10, 1915, there had been no bleeding during the previous week, which was very unusual. The patient could breathe through the right nostril freely, for the first time in months

April 21 a metastatic growth had just appeared at the inner angle of the orbit on the right, measuring 1.5 by 0.75 cm

July, 1915, the general health was excellent with no further bleeding. There was no growth to be seen in the nose, in the nasopharynx or at the inner angle of the orbit. No enlarged glands were found

October, 1915, there was a recurrence of the growth in the entire region of the middle turbinate on the right and at the inner angle of the orbit. The nasopharynx was free from growth. There were no enlarged glands

November, 1915 there was no evidence of the growth in the nose, nasopharynx or orbit

April, 1916, a second recurrence of the growth was found in the right nostril

October, 1916, the nose, nasopharynx and orbit were free from any evidence of the growth, but there were dense adhesions in the upper part of the right nostril

May, 1917, there was no evidence of any recurrence of the growth, and the general health was excellent

August, 1920, the patient was perfectly well in every way

January, 1922, the patient was healthy

*CASE 11—History*—A white woman aged 33, was admitted in October 1915, complaining of a nasal obstruction of four years' duration, with frequent and profuse bleeding from the nose and throat. There had been exophthalmos and diplopia on the left. "Polypi" had been removed from the left side of the nose every two or three months from 1912 to 1915. During the early part of 1915, a nasal operation had been necessary every month, and recently, every week. On account of the appearance of exophthalmos, she was referred for radium treatment

*Examination*—The Wassermann reaction was negative. The glands in the neck were slightly enlarged on the left. The tissue which was removed at the various nasal operations had never been examined microscopically until her admission in October, 1915

*Diagnosis*—The microscopic diagnosis was angiosarcoma

*Treatment*—Intensive treatment was given the patient between Oct 11, 1915, and Aug 30, 1916, a total of 40,900 mc hours of gamma radiation being employed at a distance of from 3 to 4 inches over the outside of both cheeks. In addition, she received 210 mc hours of gamma radiation in the nasopharynx

*Course*—February, 1916, the diplopia had disappeared, and the exophthalmos was less marked. The left side of the nose was entirely filled with a soft, vascular growth

August, 1916, the general condition was good and the patient could breathe through the left side of the nose for the first time in a year

September 1, there was a rapid recurrence of the growth both in the nose and nasopharynx, and the exophthalmos was also returning rapidly

September 25, the patient's physician wrote that she was blind and unconscious and was dying rapidly. There was no necropsy

*CASE 12—History*—A white man, aged 47, was admitted in May, 1912, complaining of a severe sore throat as the earliest symptom, nine months previ-

ously During the first month, there was a rapid enlargement of the glands on both sides of the neck He had difficulty in breathing through the nose, with tinnitus and impairment of hearing in the right ear and involvement of the third nerve on the right The glands on both sides of the neck had been removed, six months previously, at the Newark City Hospital The nose and throat were not examined at that time

*Examination*—There was no report of a Wassermann reaction At this time, there was a recurrence of enlargement of the glands in the neck The nasopharynx and the sphenoidal region on the right were entirely filled with growth

*Diagnosis*—The microscopic diagnosis was angiosarcoma

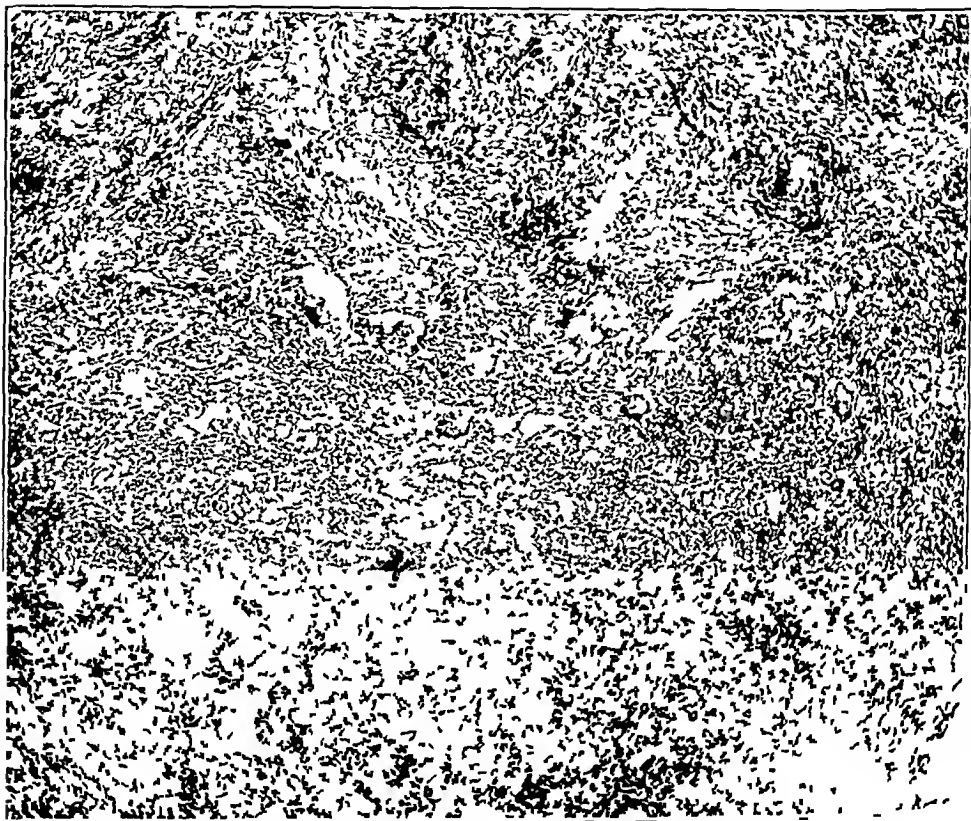


Fig 6—Angiosarcoma involving antrum, orbit, right nostril and entire nasopharynx in a boy, aged 18 years, radium treatment, well three years later

*Treatment*—At this time (1912), no radium was available, and, on account of the recurrence of the enlargement of the glands in the neck and the evidence of orbital metastases, a surgical operation was not advised

*Course*—We have been unable to trace the patient, but this case is included in order to contrast the result with that in Case 1

**CASE 13—History**—A white boy, aged 18, was admitted in June, 1916 He had experienced difficulty in breathing through the right side of the nose, two years previously There had been a purulent discharge from the right nostril for three months, with frequent hemorrhages from the nose and mouth He also had a bilateral impairment of hearing with exophthalmos on the right

and a swelling over the right antrum. The patient had had frequent nasal colds since early childhood. There was no history of headaches, nor of bleeding, and there was no metastasis to the glands in the neck.

*Examination*—The Wassermann reaction was negative. The general condition was good, but the entire nasopharynx was filled with growth, including the right nostril and right antrum, not involving the hard palate.

*Diagnosis*—The microscopic diagnosis was angioma or angiosarcoma.

*Treatment*—Between June 21, 1916, and April 28, 1917, the patient had received heavy external irradiation over the outside of the right cheek, employed at a distance of from 2 to 5 inches, depending on the length of the individual treatments. The total treatment amounted to 53,300 mc hours of gamma radiation. The most marked effect of the radium was the cessation of the spontaneous hemorrhages.

*Course*—June 26, 1916, the first treatment, given five days previously, had resulted in a marked reduction in the size of the growth in the right nostril. There was a swelling over the right antrum but the exophthalmos was much diminished.

June 28, the patient's face looked almost normal.

October, 1916, there was a recurrence of the swelling over the right side of the face, and the right nostril was filled with a sloughing tumor mass.

December, 1916, the general condition was improving, but there was no gain in weight. The right nostril and nasopharynx were filled with growth.

April, 1917, the local condition was about the same as at the last notation. The general condition was good, and no enlarged glands were found in the neck.

March, 1918, Dr F W Janney reported that there was no evidence of a growth in the antrum, orbit, nose or nasopharynx. The middle turbinate on the right was enlarged, but otherwise appeared normal.

*CASE 14—History*—A white man, aged 26, was admitted in February, 1919, complaining of a nasal obstruction and a purulent discharge on the left, of three years' duration. He had had frequent and severe hemorrhages from the nose, and numerous nasal operations had been performed without relief of the symptoms.

*Examination*—The Wassermann reaction was negative. There were moderately enlarged glands in the neck on the left but none were palpable on the right. The right side of the nose appeared normal, while the left side of the nose and the left half of the nasopharynx were filled with growth. There was no ulceration and no trouble with the ears. A roentgen-ray examination of the chest proved negative.

*Diagnosis*—The microscopic diagnosis was angioma.

*Treatment*—Between Feb 6, 1919, and Aug 20, 1920, the patient received very intensive treatments, a total of 22,000 mc hours of gamma radiation being employed at 4 inches, and 250 mc hours of gamma radiation being used directly against the growth in the nasopharynx and a total of 16½ mc of radium emanation in glass capillary points being implanted directly in the growth and left. This implantation treatment was equivalent to 1,850 mc hours.

*Course*—February, 1920, the condition in the left nostril and nasopharynx was about the same as in February, 1919. There was no evidence of any extension of the growth.

June, 1920, the growth had decreased in size, and the patient could breathe through the left nostril for the first time in four years. The enlarged glands in the neck on the left had disappeared.

October, 1920, the patient breathed freely through the left nostril but not so well through the right. There was still a tumor in the left nostril posteriorly, and also a globular tumor in the posterior nasopharynx. The patient had received tremendous treatment, and the result so far had been very good.

December, 1921, there had been no hemorrhages during the past year, and the growth had entirely disappeared from the nose and nasopharynx. Both sides of the nose appeared normal, with the exception of adhesions in the upper part of the left nostril. The general health was excellent. Subjectively and objectively, he seemed well.

#### LYMPHOSARCOMA OF THE NASOPHARYNX

**CASE 15—History**—A white man, aged 47, was admitted in March, 1914. The earliest symptom had been an obstruction of the left eustachian tube. The ear symptoms were thought to be due to hypertrophied adenoids, and from March, 1913, to January, 1914, the "adenoids" were removed five times under local anesthesia, but there had been a rapid recurrence. Although large masses of tissue had been removed from the nasopharynx on each occasion none of this tissue had been saved for examination. There was complete nasal obstruction in March, 1914. Enlarged glands had been found in the neck on the left, near the angle of the jaw. There had been no history of bleeding and no pain.

**Examination**—The Wassermann reaction was negative. The growth was primary in the nasopharynx, it did not involve the nasal cavities, the soft palate, the orbit, the cranial cavity or any of the cranial nerves. The differential blood count was normal. There was no general glandular enlargement, and the abdominal organs were normal. A roentgen-ray examination of the chest was normal.

**Diagnosis**—The microscopic diagnosis was lymphosarcoma (Fig. 7).

**Treatment**—During March, 1914, the patient was given very mild radium treatment. March 4, 20, and 24, a total of 250 mc hours of gamma radiation was employed in the nasopharynx and 800 mc hours was applied over the cervical glands, at a distance of 1 inch.

October, 1918, an exploratory operation was performed, and radium emanation was implanted in eight glass capillary points, in the abdominal growth. In addition to the radium treatment, the patient was treated with Fowler's solution for four years, according to a definite schedule. Every effort was made to keep him in the best possible physical condition.

**Course**—March 4, 1914, 600 mg of radium bromid was applied directly in the nasopharynx for one hour.

March 9, most of the growth had disappeared, but there was a large sloughing area in the nasopharynx. The patient could breathe freely through the nose for the first time in three months.

May 16, the nose, nasopharynx and eustachian tubes appeared normal, and there were no palpable glands in the neck. The general condition was excellent. For the next four years, the patient was examined every six months, and there never was any recurrence in the nose, throat or glands of the neck. He weighed 165 pounds.

October 1918 the patient complained of a slight pain in the abdomen after eating, a swelling in the left side of the abdomen, and a loss of 10 pounds during the previous month. A large hard mass filled the entire left half of the abdomen. A roentgenogram of the chest revealed that the lungs and the mediastinum were normal.

October 25, an exploratory incision was made, with the implantation of radium points

November 1, the abdominal tumor had entirely disappeared, i e, it was no longer palpable

November 16, there was a rapid recurrence, and the growth was felt in Douglas' pouch At a second exploratory operation, disseminated nodules were found in the abdominal wound, and everywhere in the mesentery No treatment was given

Nov 17, 1918, the patient died Necropsy was not permitted

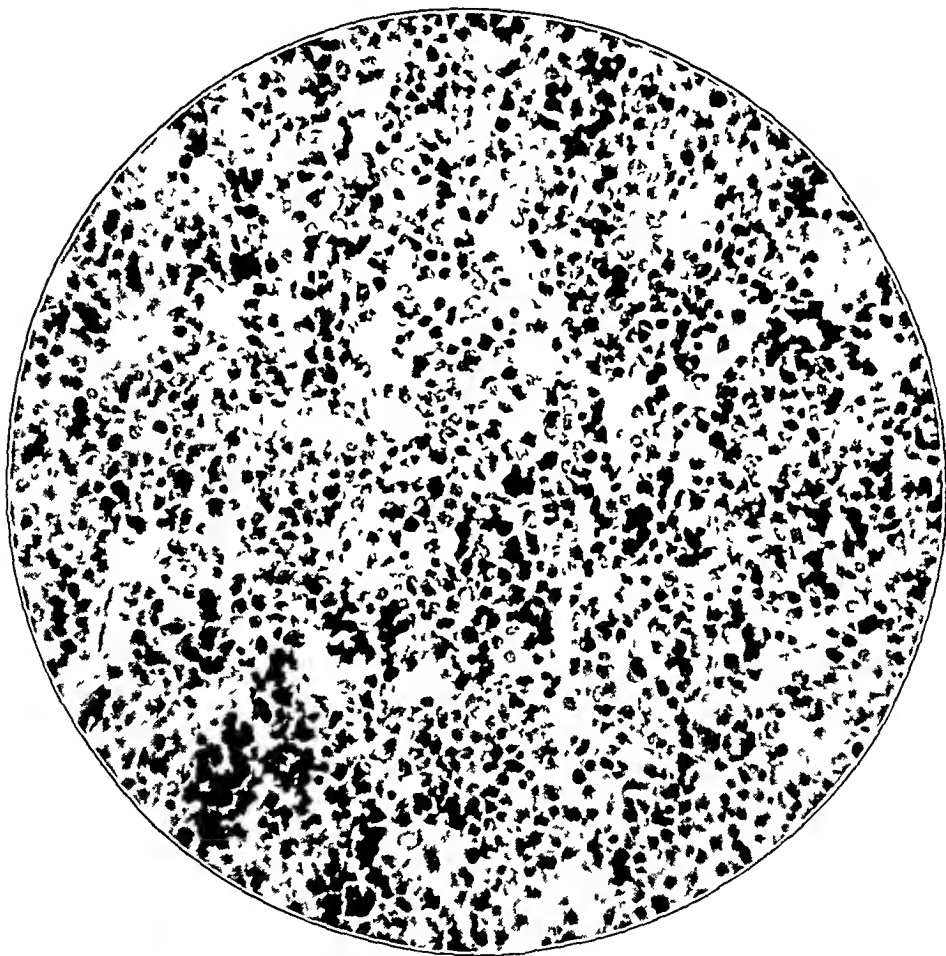


Fig 7—Lymphosarcoma in a man, aged 47, which filled the entire nasopharynx and involved the cervical lymph glands, radium treatment, well for four years, growth then appeared in the retroperitoneal and mesenteric glands for the first time, disappeared after radium treatment but rapidly recurred, growth in nasopharynx and cervical glands never recurred during the four and one-half years of observation

CASE 16—*History*—A white girl, aged 17, was admitted in November, 1919, complaining of a nasal obstruction and a slight pain across the bridge of the nose She had been operated on for the removal of tonsils and adenoids in June, 1916, which had relieved the nasal obstruction for one year, but it was



worse at the time of admission than ever before. There was no history of bleeding. The glands of the neck had not been involved.

*Examination*—The Wassermann reaction was negative. The posterior half of the right nostril and the entire nasopharynx were filled with growth. There was no ulceration. All other examinations were negative.

*Diagnosis*—The microscopic diagnosis was lymphosarcoma.

*Treatment*—November, 1919. Between Nov 8, 1919, and Sept 20, 1920, the patient received very intensive irradiation, a total of 22,000 mc hours of gamma irradiation being employed at a distance of from one-half to 3 inches over the right and left sides of the face, and 450 mc hours of gamma radiation being used directly in the nasopharynx.

Feb 26, 1920, the remains of the tumor in the nasopharynx were removed, and radium treatment was continued.

*Course*—December, 1919, the growth was still present, but was much smaller, and the patient was able to breathe freely through the nose for the first time in two years.

February, 1920, there was no evidence of the growth in the nose, but it was still present in the nasopharynx. This was removed at operation.

March, 1920, there was a small nodule of the growth near the right eustachian tube, otherwise, the nose and the nasopharynx appeared normal.

June, 1920, there was no evidence of growth in the nose, nasopharynx or the glands of the neck. The general condition was excellent.

February, 1921, the general health was good, and there was no evidence of a recurrence, locally or elsewhere in the body.

*CASE 17—History*—A white woman, aged 35, was admitted in January, 1917, with a fractured nose, the result of an automobile accident, eight months previously, with an increasing nasal obstruction, and, recently, an impairment of hearing on the right and a nasal voice.

*Examination*—The Wassermann reaction was negative. The growth apparently had originated in the posterior nasal cavity on the right, almost completely filling the nasopharynx. The orifice of the right eustachian tube could not be seen. The glands of the neck were just palpable on both sides. There was no bleeding and no pain.

*Diagnosis*—The microscopic diagnosis was lymphosarcoma.

*Treatment*—Between Feb 3, 1917, and March 17, 1917, the patient received 22,400 mc hours of external radiation, employed at a distance of 3 inches over the right and left sides of the face, 150 mc hours of gamma radiation was used directly against the growth in the nasopharynx. In addition to the radium treatment, the growth was removed under ether anesthesia, and the nasal septum was straightened.

*Course*—July, 1917, the nose and the nasopharynx appeared normal.

October, 1919, the patient was perfectly well. There were no palpable glands in the neck and no evidence of the growth.

October, 1920, the patient was perfectly well. The radium treatment did not affect the salivary glands.

January, 1922, the patient was well.

*CASE 18—History*—A white man aged 45, was admitted in November, 1914, complaining of an impairment of hearing in the right ear. A growth, which was found to be the cause of the ear trouble, had been removed from the nasopharynx in June, 1913, followed by a rapid recurrence. No microscopic study

of the tissue was made and it was assumed to be syphilitic. He had been treated with silver, potassium iodid and arsphenamin, without any benefit. He had had a postnasal discharge for fifteen years. Operation had been performed on the sphenoids, ethmoids and antrums. He had severe tonsillitis in July, 1913, for eight weeks, losing 30 pounds in weight. A general enlargement of the glands occurred, the cervical and axillary glands on the right being as large as hickory nuts.

*Examination*—The Wassermann reaction of both the blood and the spinal fluid was negative. The nasopharynx was entirely filled with growth, pushing the soft palate forward and involving the lateral pharyngeal wall on the right. The right side of the nose was also filled with growth. There was no infection in the ears, no pain and no bleeding. The differential blood count revealed (1) increase in number of transitionals, 76 per cent, (2) increase in number of platelets, (3) increase in number of eosinophils, 8 per cent.

*Diagnosis*—The microscopic diagnosis was lymphosarcoma.

*Treatment*—From Dec 9, 1914, to Oct 15, 1915, the patient received moderately heavy external irradiations, amounting to 9200 mc hours of gamma radiation employed at a distance of from 1 to 2½ inches, centered over the right and left sides of the neck, the right and left axillae and the right and left groins. He also received 130 mc hours in the nasopharynx (screened with rubber).

*Course*—Dec 9, 1914, thirty-six hours after the first radium application, the patient was able to breathe through the left side of the nose for the first time in four months. On the third day, he could breathe through the right side of the nose for the first time in eighteen months. On the seventh day, the right eustachian tube opened, and the hearing returned to normal.

Jan 8, 1915, there was no evidence of any growth in the nose or in the nasopharynx. The enlarged axillary and inguinal glands never decreased in size. It was thought that their enlargement was due to chronic skin diseases.

December, 1918, a letter stated that the patient died, December 21. No cause was given, and no necropsy was performed.

*CASE 19—History*—A white woman, aged 22, was admitted in December, 1916. She had been a mouth breather since early infancy, and had had frequent colds. The tonsils and adenoids had been removed in November, 1916. Two weeks later, a swelling had been noted—a tumor—in the soft palate on the left. The operative wounds had healed perfectly. The swelling of the soft palate had been thought to be due to infection, and was incised four days before admission. The fulness of the parotid region had been due to metastasis under the zygoma.

*Examination*—The Wassermann reaction was negative. There was a large, hard, firmly fixed growth involving the soft palate on the left and the left lateral wall of the pharynx and nasopharynx, not involving the nose. This was all submucous. There was no ulceration, no otitis media. The differential blood count was normal, and the Pirquet reaction negative. The glands of the neck were not enlarged. There was no general glandular enlargement.

*Diagnosis*—The microscopic diagnosis was lymphosarcoma (Fig 8).

*Treatment*—December, 1916, the large tumor mass in the soft palate and lateral wall of the pharynx was removed. After the overlying mucous membrane was split, the tumor mass shelled out very easily. The wound was left open, and radium was employed directly in the wound. No infection occurred, and after three weeks, the wound had healed. Between Dec 16 1916, and Jan

23, 1918, the patient received very intensive radium treatments, consisting of 226,000 mc hours of gamma radiation employed at a distance of from 3 to 5 inches over the right and left sides of the face. In addition, she received 350 mc hours of gamma radiation, employed directly in the nasopharynx.

*Course*—In April, 1917, the general condition was good, and there were no enlarged glands in the throat or the nasopharynx. The mass under the zygoma had disappeared.

June, 1917, there was a fulness of the lateral wall of the pharynx on the right and a recurrence of fulness under the zygoma on the left.

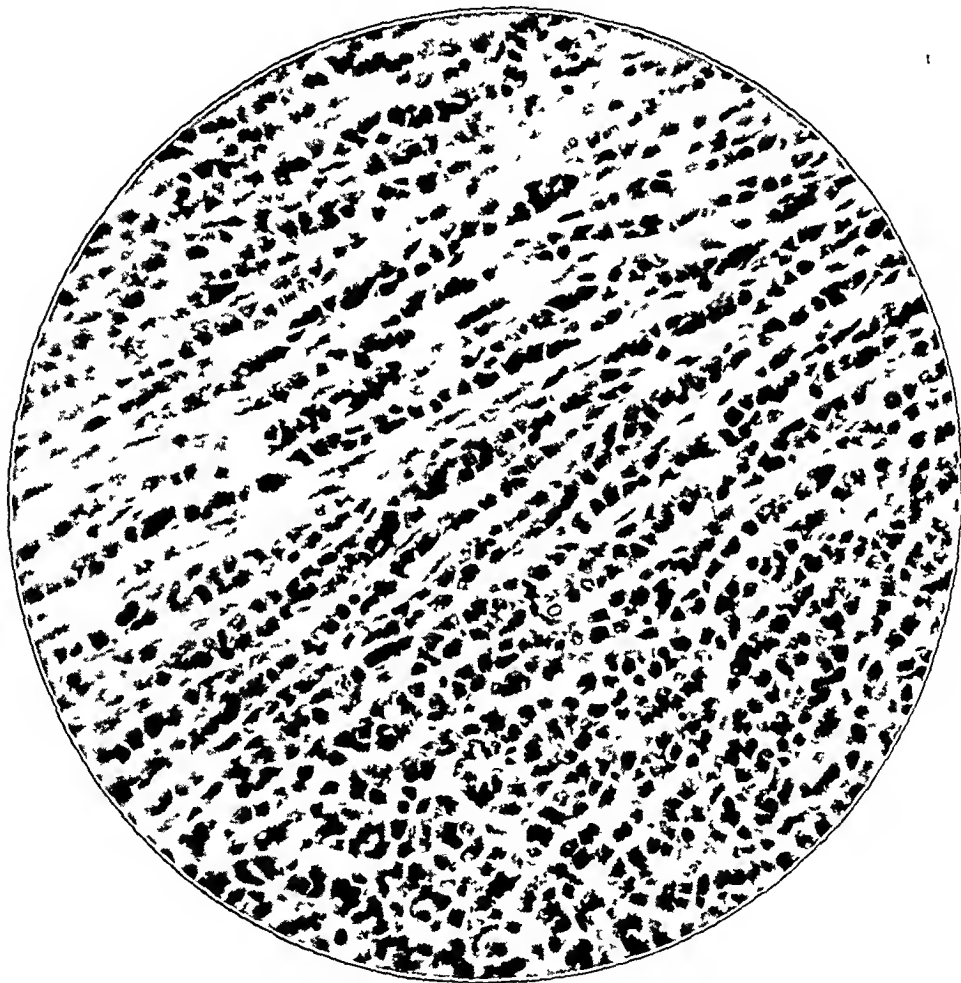


Fig 8—Lymphosarcoma in a girl, aged 2, well for eight months after combined operative and radium treatment, radium had no effect on the recurrent growth, arrangement of the cells suggests endothelioma. Compare with illustrations in an article by Pollak.<sup>10</sup>

July, 1917, there was no evidence of the growth anywhere.

October, 1917, there was a small mass surrounding the orifice of the left eustachian tube, and again there was a swelling under the left zygoma.

December, 1917, the growth has rapidly recurred in spite of the irradiation. There was a large mass in the left side of the pharynx, nasopharynx and the soft palate.

February, 1918, the patient died at home. No necropsy was performed.

*CASE 20—History*—A white girl, aged 10, was admitted in January, 1920. She had been easily fatigued during the previous year. The tonsils had been removed in September, 1919, because of pain in the joints. One month later, a swelling of the left side of the jaw and neck had been noticed. There had been no pain or bleeding, and the hearing had been gradually impaired on the left. A tumor, which had appeared following the removal of the tonsils and adenoids, had been found accidentally in the throat. She had gained 10 pounds since September, 1919, and now weighed 85 pounds.

*Examination*—The Wassermann reaction was negative. There was a swelling of the left half of the soft palate and of the left posterior pillar, involving the entire nasopharynx. The voice was nasal. The anterior nares were normal. A roentgenogram of the chest was normal. There was no general glandular enlargement. The glands were enlarged at the angles of the jaw, but more on the left, with a fulness over the left side of the face. The Pirquet reaction was negative. There was postural albuminuria (?), and secondary anemia.

*Diagnosis*—No tissue was removed for a microscopic examination, but the clinical diagnosis was lymphosarcoma.

*Treatment*—Between Jan 7, 1920, and Feb 14, 1920, the patient received 9,000 mc hours of gamma radiation, from a distance of 3 inches, centered over the left side of the neck. There was no evidence of growth at the latter date. She was given very heavy irradiation over the occipital region and over the right femur between September 6 and 12, 1920.

*Course*—March, 1920, all evidence of the growth had disappeared from the mouth, and there were no enlarged glands in the neck. A small amount of tissue in the midline of the nasopharynx was seen that grossly resembled adenoid tissue. The eustachian orifices were clear.

June, 1920, the patient was subjectively well. She had a clear voice, the pharynx and the nose were normal, and examination of the ears was negative. Adenoid tissue appeared to be present in the nasopharynx, and there were some adhesions between this and the eustachian tube on the right.

September, 1920, there were metastasis to the brain, choked disk and strabismus. A roentgenogram of the femur revealed the periosteum lifted and thickened. The patient died, and no necropsy was performed.

*CASE 21—History*—A white girl, aged 14, was admitted Feb 23, 1918. A lump had been noticed in the soft palate in December, 1917. Three weeks before admission, she had had her tonsils removed, and ten days later, there had been a rapid increase in the size of the growth.

*Examination*—A tumor was visible when the soft palate was lifted, but the eustachian tube and the glands of the neck were not involved. There was no history of bleeding.

*Diagnosis*—The microscopic diagnosis was lymphosarcoma.

*Treatment*—Between Feb 23, 1918, and March 30, 1918, the patient received very intensive irradiation, as much as could be employed with safety during this short period. A total of 64,700 mc hours of gamma radiation from a distance of 5 inches was centered over the right and left sides of the neck, and one treatment was also given over the metastasis in the lower abdomen. In addition, she received very mild treatment in the pharynx.

*Course*—March 2, 1918, the growth had almost entirely disappeared, and no palpable glands were found in the neck.

March 7, 1918, the growth in the soft palate was about 1 cm in diameter

March 15, 1918, there was a rapid recurrence, and the growth was almost as large as on admission

March 28, 1918, there was a large mass in the left lower part of the abdomen, the size of an egg, also an evidence of metastasis to the liver

June, 1918, the patient died, and no necropsy was performed

*CASE 22—History*—A white woman, aged 23, was admitted in December, 1916. The earliest symptom had been impairment of hearing on the left, which had occurred six months previously. The glands on the left side of the neck were enlarged. She suffered pain in the left side of the head as well as in the teeth on the left.

*Examination*—The Wassermann reaction was negative. The growth originated from the vault and the left lateral wall of the nasopharynx. The mucous membrane over it was intact. There was no history of bleeding. A roentgenogram of the sinuses and chest was negative, and the blood count was normal.

*Diagnosis*—No tissue was removed for a microscopic examination, but the clinical diagnosis was lymphosarcoma.

*Treatment*—Between Dec 27, 1916, and June 5, 1917, the patient received very intensive irradiation, an external treatment of 81,800 mc hours of gamma radiation being employed at 3 inches over the right and left sides of the face, and light treatments being given in the nasopharynx, totaling 120 mc hours of gamma radiation.

*Course*—January, 1917, the patient had gained 11 pounds in weight. The glands of the neck were smaller, and the hearing on the left was normal.

February, 1917, the growth in the nasopharynx had disappeared, and the glands were just palpable.

June, 1917, no evidence of the growth was seen in the nose or throat. The glands were not palpable.

July 16, 1920, the patient wrote that she was in splendid health, looked well and that there was no evidence of any return of the trouble. She weighed 139 pounds.

June, 1922, the glands in the neck had recurred, and she had a septic temperature. The patient was receiving radium treatment from Dr C J Miller of New Orleans.

*CASE 23—History*—A white man, aged 71, was admitted Feb 7, 1918, complaining of a sore throat of four months' duration, and pain on swallowing for the previous ten days. He had been given arsphenamin without any improvement, and had lost 20 pounds during the past four months.

*Examination*—The Wassermann reaction was negative. The entire nasopharynx was filled with a mass which had largely destroyed the soft palate and the left tonsil, the cavity being the size of a hen's egg. He had had frequent attacks of sore throat for fifteen or twenty years, which became worse every year.

*Diagnosis*—The microscopic diagnosis was lymphosarcoma.

*Treatment*—Between Feb 7, 1918, and July 26, 1918, the patient received intensive irradiation, both from the outside and in the nasopharynx, a total of 47,200 mc hours of gamma radiation at a distance of from 3 to 5 inches being employed over the right and left sides of the neck, and 450 mc hours directly against the tumor.

*Course*—Feb 21, 1918, the patient was improved, and the growth in the throat was smaller

Feb 27, 1918, he was able to swallow with less pain

March 27, 1918, the patient had improved wonderfully, and the growth in the throat was nearly gone

April 27, 1918, the tumor was smaller, owing to the heavy irradiations given every other day

May 14, 1918, the general condition was excellent, but there was still a little thickening on the left side of the soft palate

May 28, 1918, the growth was beginning to recur, and the radium treatments inside the mouth caused a great deal of irritation, without seeming to cure

June 15, 1918, no enlarged glands were found in the neck, but there was considerable growth in the pharynx

July 8, 1918, the glands were just palpable in the posterior triangles of the neck. There was a large growth in the nasopharynx, which covered the left eustachian tube and extended down the left lateral wall of the pharynx, involving the tonsil, soft palate, base of the tongue and the epiglottis. Both sides of the nose appeared normal

October, 1918, the patient died, and no necropsy was performed

*CASE 24—History*—A white man, aged 22, was admitted in December, 1920, complaining of a nasal obstruction, of four months' duration, and pain in the left side of the face and in the upper and lower teeth, as well as frontal headache. There had been no history of bleeding either from the mouth or the nose. There was jaundice and a severe pain referred to the lower dorsal and upper lumbar regions. A roentgenogram of the spine was negative

*Examination*—The Wassermann reaction was negative. The glands were just palpable on both sides of the neck. The growth apparently arose from the posterior part of the septum on the left, filling the entire nasopharynx. There was a slight exophthalmos on the left and also an impairment of the sensation of the second and third division of the trigeminus on the left, the impaired hearing being due to the eustachian tube obstruction. The blood count was leukocyte, 9,000, eosinophils, 0.5 per cent, lymphocytes, 11 per cent, differential count mononuclears, 65 per cent, polymorphonuclears, 81.5 per cent, basophils, 0, platelets, slightly increased

*Diagnosis*—The microscopic diagnosis was lymphosarcoma

*Course*—Dec 18, 1920, 3,930 mc at 5 inches was applied for two hours over each side of the face

Dec 24, 1920, 3,849 mc at 5 inches was applied for one and one-half hours over each side of the nose. The patient returned to the Walter Reed Hospital where he died Feb 5, 1921

*Necropsy*—The growth had invaded the left frontal sinus, ethmoids, orbit and antrum. The left sphenopalatine ganglion was surrounded with growth. The mediastinum was not involved. There were no liver or kidney metastases. A metastatic growth was found in the head of the pancreas, causing almost complete obstruction of the common duct. An examination of the gastrointestinal tract was negative. There were no metastases to the brain

*Comment*—The irradiation in this case did not result in any evident decrease in the size of the nasopharyngeal growth. The necropsy revealed that the tumor involved the ethmoidal region, frontal sinus, orbit and sphenopalatine fossa on the left. The tumor of the nasopharynx and accessory sinuses showed great masses of lymphocytic cells with relatively large, densely staining nuclei, sur-

rounded by a narrow zone of neutral staining cytoplasm. The stroma was scant and delicate in structure. The cell masses came up to the epithelium but did not appear to invade or destroy it. Sections showed bone, however, being destroyed. The diagnosis was lymphosarcoma of the lymphocyte cell type (Paul A. Schulc, Chief Laboratory Service, Walter Reed General Hospital).

#### OTHER TYPES OF SARCOMA OF THE NASOPHARYNX

*CASE 25—History*—A white boy, aged 4½ years, was admitted in December, 1917, complaining of nasal obstruction and discharge from the ears, but no bleeding. The growth in the nose had first been noticed six months previously, one month after removal of the tonsils and adenoids.

*Examination*—The Wassermann reaction was negative. The growth had apparently originated in the nasopharynx and had grown rapidly into both nostrils and downward into the pharynx, resulting in complete nasal obstruction and great difficulty in breathing through the mouth. The glands of the neck were not involved.

*Diagnosis*—The microscopic diagnosis was spindle-cell sarcoma (Fig 21).

*Treatment*—On two occasions it was necessary to remove the growth from the pharynx so that the child could breathe through the mouth and swallow. Large doses of radium were applied directly to the base of the growth at each operation. Between Oct 3, 1917 and Dec 22, 1917, the patient received very intense irradiation. A total of 37,600 mc hours of gamma radiation was applied over the right and left sides of the face at a distance of 4 inches. In addition, 150 mc hours of gamma radiation was applied directly in the nasopharynx against the tumor.

*Course*—December, 1917. Before admission to the hospital, the patient had received fourteen radium treatments with the result that for a time the growth had entirely disappeared. It rapidly recurred, and after admission the growth was removed and 500 mc of radium was applied directly on the points of attachment of the growth for two minutes in five areas (in all a total of ten minutes). The growth recurred within two weeks. Heavy external irradiation was employed and again radium was applied directly to the growth in several areas (542 mc for a total of ten minutes).

January 1918, the growth had not disappeared from the nasopharynx, but it was no longer visible in the mouth or in either side of the nose. Two hundred and seventy-nine mc of radium was applied directly on the growth in the nasopharynx for sixteen minutes. There were no enlarged glands in the neck.

March, 1918, the patient died. The growth rapidly recurred and radium had no effect. The orbit and the intracranial cavity were invaded.

*CASE 26—History*—A white man, aged 51, was admitted in November, 1914, complaining of difficulty in breathing through the nose and a muffled voice of three months' duration. There had been no bleeding.

*Examination*—The Wassermann reaction was negative. The growth had originated on the posterior part of the septum or in the nasopharynx. It was smooth, hard and covered with intact mucous membrane. The glands of the neck were not enlarged.

*Diagnosis*—The microscopic diagnosis was spindle-cell sarcoma (alveolar arrangement, Fig 9).

*Treatment*—The patient received mild external irradiation, Jan 26, 1915, 6,100 mc hours of gamma radiation being employed at a distance of 2 inches.

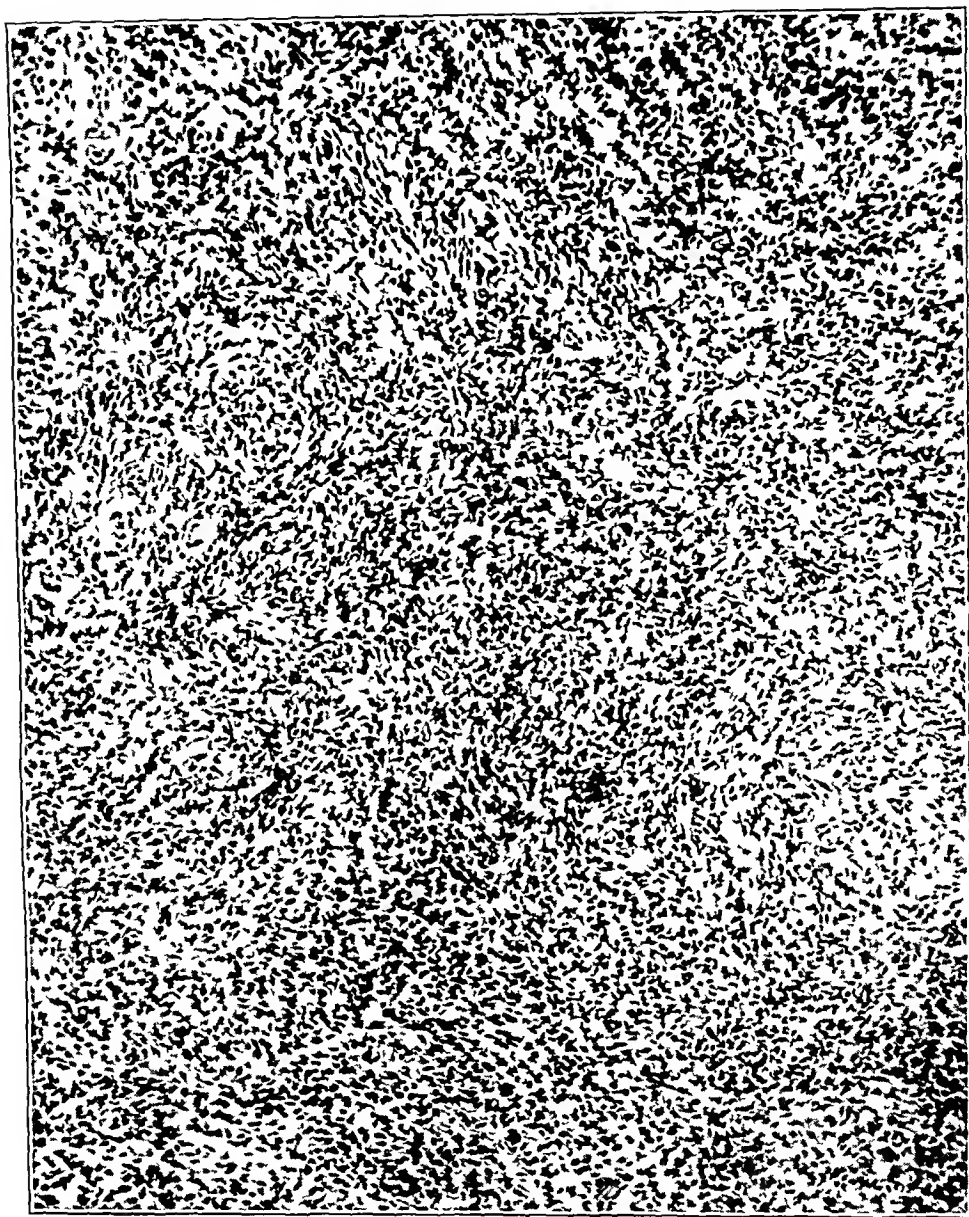


Fig 9—Spindle-cell sarcoma in a man, aged 51, whose chief symptom was nasal obstruction, after irradiation there was marked improvement for six months, then rapid recurrence and intracranial invasion, alveolar arrangement may be noted



February 20, 564 mc hours of gamma radiation was applied directly in the nasopharynx. March 29, 1,000 mc hours of gamma radiation was applied directly in the growth by implantation.

*Course*—February, 1915, the radium had had little effect on the growth in the nasopharynx. The growth involved the right side of the nose and had destroyed the vomer. The patient was suffering severe pain.

July, 1915, there was fixation of the jaw, as well as intracranial and orbital involvement, abducens paralysis and visual disturbances. The growth had involved the right antrum, ethmoids and sphenoid. The patient died.

*CASE 27—History*—A white boy, aged 16, was admitted in June, 1918, complaining of nasal obstruction of one and one-half years' duration. He had had no headache, no ear symptoms, and there was no history of bleeding.

*Examination*—The Wassermann reaction was negative. The growth had apparently originated just below the posterior end of the middle turbinate on the left. It filled the nasopharynx and caused obstruction of the right nostril by pushing the septum over. There was no tumor in the right nostril. The glands of the neck were palpably enlarged on both sides.

*Diagnosis*—The microscopic diagnosis was myxosarcoma (Fig 10).

*Treatment*—Between June 27, 1918, and March 13, 1920, the patient received very intensive irradiation externally, applied to both sides of the head at a distance of from 2 to 5 inches, totaling in all 83,000 mc hours of gamma radiation applied directly to the surface of the growth by inserting emanation tubes into the nasopharynx, and a total of 1,800 mc hours of gamma radiation applied by inserting two capillary tubes, each containing 5 mc of radium emanation, into the tumor in the nasopharynx. The details of the radium treatment in this case are given in the accompanying table.

*Course*—September, 1918, the growth had greatly decreased in size.

April, 1918, the patient had had twenty-eight radium treatments, both intranasal and external, with but little permanent improvement. The nasal obstruction still remained.

May, 1919, the patient had gained 6 pounds in weight.

August, 1919, the growth had decreased in size again.

November 1919, the growth in the nose and nasopharynx was sloughing. The glands in the neck were about the size that they were a year previously. The soft palate was perforated on the left side as a result of a radium burn.

March, 1920, the patient was much improved. The growth had disappeared from the left side of the nose and from the left side of the nasopharynx. The orifice of the right eustachian tube was still obscured by growth.

June 1920 there was no growth in the nose. There was still a small growth in the right side of the nasopharynx. The patient breathed normally through the nose.

Aug 17, 1921, there was slight irritation in the nasopharynx on the left side, but no growth whatever. There was a hole in the soft palate which interfered with phonation.

*CASE 28—History*—A white man, aged 24, was admitted in May, 1918, complaining of nasal obstruction of six months' duration. There was impaired hearing, owing to obstruction of both eustachian tubes, but no history of bleeding.

*Examination*—The Wassermann reaction was negative. There was a retropharyngeal growth covered with smooth mucous membrane visible in the mouth.

## DETAILED NOTES OF RADIUM TREATMENT IN CASE 27

Date	Dosage Mg	Distance	Site of Application	Duration of Application
June 27, 1918	3657	6 in	Left side of nose	1 hour
June 30, 1918	3629	6 in	Left side of nose	3 hours
July 3, 1918	3374	5 in	Both sides of nose	1 hour
July 10, 1918	3657	4 in	Left side of nose	2 hours
July 14, 1918	2714	4 in	Left side of nose	2 hours
July 17, 1918	4009	4 in	Left side of nose	2 hours
July 21, 1918	3921	4 in	Left side of nose	1 hour
July 25, 1918	3695	5 in	Left side of nose	1 hour
July 28, 1918	3225	5 in	Left side of nose	1 hour
Aug 1, 1918	4093	5 in	Left side of nose	1 hour
Sept 13, 1918	3046	3 in	Both sides neck	Total 1½ hours
	500		Direct in each nostril	4 min
Sept 16, 1918	3006	3 in	Over angles of jaw	45 minutes each
Sept 20, 1918	3651	3 in	Over angles of jaw	45 minutes each
Sept 24, 1918	2824	3 in	Over angles of jaw	30 minutes each
Nov 30, 1918	378		Direct to growth	10 minutes
Dec 3, 1918	423		Direct to growth	10 minutes
Dec 4, 1918	353		Direct to nose	5 minutes
Dec 6, 1918	245		Direct to nose	5 minutes
Dec 9, 1918	773	3 in	To nose	One half hour
Dec 10, 1918	282		Direct to nose	10 minutes
Dec 11, 1918	2981	4 in	To nose	2 hours
Dec 13, 1918	2101	3 in	To nose	15 minutes
Mar 9, 1919	1042		Direct to nasopharynx	4 minutes
Mar 11, 1919	774		Direct inside nose	6 minutes
Mar 15, 1919	883		Direct inside nose	6 minutes
Mar 13, 1919	1348		Direct inside nose	6 minutes
Mar 26, 1919	972		Direct inside nose	4 minutes
Mar 30, 1919	874		Direct inside nose	4 minutes
Apr 1, 1919	945		Direct in nose	4 minutes
Apr 4, 1919	675		Direct inside nose	3 minutes
Apr 7, 1919	395		Direct inside nose	5 minutes
Apr 9, 1919	855		Direct inside nose	6 minutes
Apr 11, 1919	1046		Direct in nasopharynx	3 minutes
Apr 14, 1919	876		Direct in nasopharynx	4 minutes
Apr 16, 1919	903		Direct in nasopharynx	3 minutes
Apr 18, 1919	583		Direct in nasopharynx	4 minutes
Apr 21, 1919	364		Direct in nasopharynx	5 minutes
Apr 23, 1919	938		Direct in nasopharynx	3 minutes
Apr 27, 1919	858		Direct in nose	4 minutes
Apr 29, 1919	1167		Direct in nose	3 minutes
May 1, 1919	811		Direct in nose	4 minutes
May 3, 1919	563		Direct in nose	4 minutes
May 5, 1919	391		Direct in nose	5 minutes
May 7, 1919	973		Direct in nose	3 minutes
May 9, 1919	675		Direct to throat	2 minutes
May 19, 1919	372		Direct to nasopharynx	3 minutes
May 21, 1919	973		Direct inside nose	1 minute
May 23, 1919	670		Direct to nasopharynx	2 minutes
Aug 9, 1919	485		Direct to nasopharynx	5 minutes
Aug 12, 1919	280		Direct to inside of nose	5 minutes
Aug 15, 1919	682		Direct to inside of nose	5 minutes
Aug 18, 1919	404		Direct to nasopharynx	5 minutes
Aug 21, 1919	One 4 mc		Needle implanted into pharynx	
Dec 1, 1919	One 5 mc		Needle inserted in growth through nose	
Mar 13, 1920	872		Direct to nasopharynx	13 minutes

## SUMMARY

## Total Treatments

14½ gr hrs at 6 inches  
 18 gr hrs at 5 inches  
 30½ gr hrs at 4 inches

18¾ gr hrs at 3 inches  
 1⅓ gr hrs direct  
 9 mc implanted in growth

The growth did not involve the nasal cavities. The glands of the neck were enlarged on the right (metastatic), but smaller on the left. There was no evidence of orbital or intracranial involvement. The differential blood count was normal.

*Diagnosis*—The microscopic diagnosis was round-cell sarcoma.

*Treatment*—Between May 18, 1918, and Jan. 28, 1919, intensive radium treatment was given, consisting of 72,700 mc. hours of gamma radiation at 5 inches,

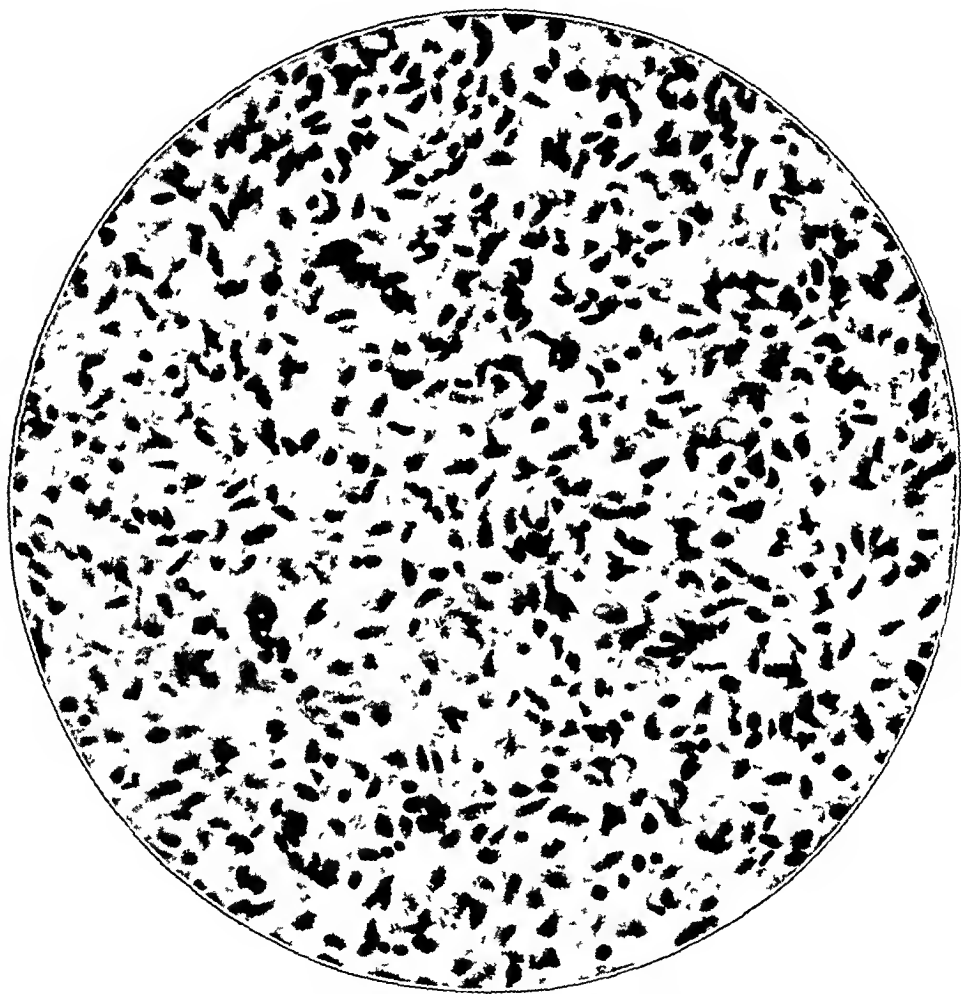


Fig 10—Myxosarcoma of the nose and nasopharynx in a boy, aged 16, complete nasal obstruction for one and one-half years before irradiation, well three years later.

centered over the right and left sides of the face. He also received 480 mc. hours of gamma radiation in the nasopharynx.

*Course*—June, 1918, there was no improvement.

October, 1918, the glands in the neck had almost disappeared. The growth in the nasopharynx was much smaller, and the patient had gained in weight.

April, 1919, cachexia was present. The patient had been much worse during the previous three months. Enlargement of the glands in the neck had recurred. There was weakness of the left facial and spinal accessory nerves. A roentgenogram revealed small mediastinal glands for the first time.

October, 1919, the patient died. The growth had apparently involved the cervical spine and had caused complete paralysis.

**CASE 29—History**—A white boy, aged 16, was admitted in May, 1919, complaining of nasal obstruction. He had had several nasal operations during the previous year. The glands in the neck were not enlarged.

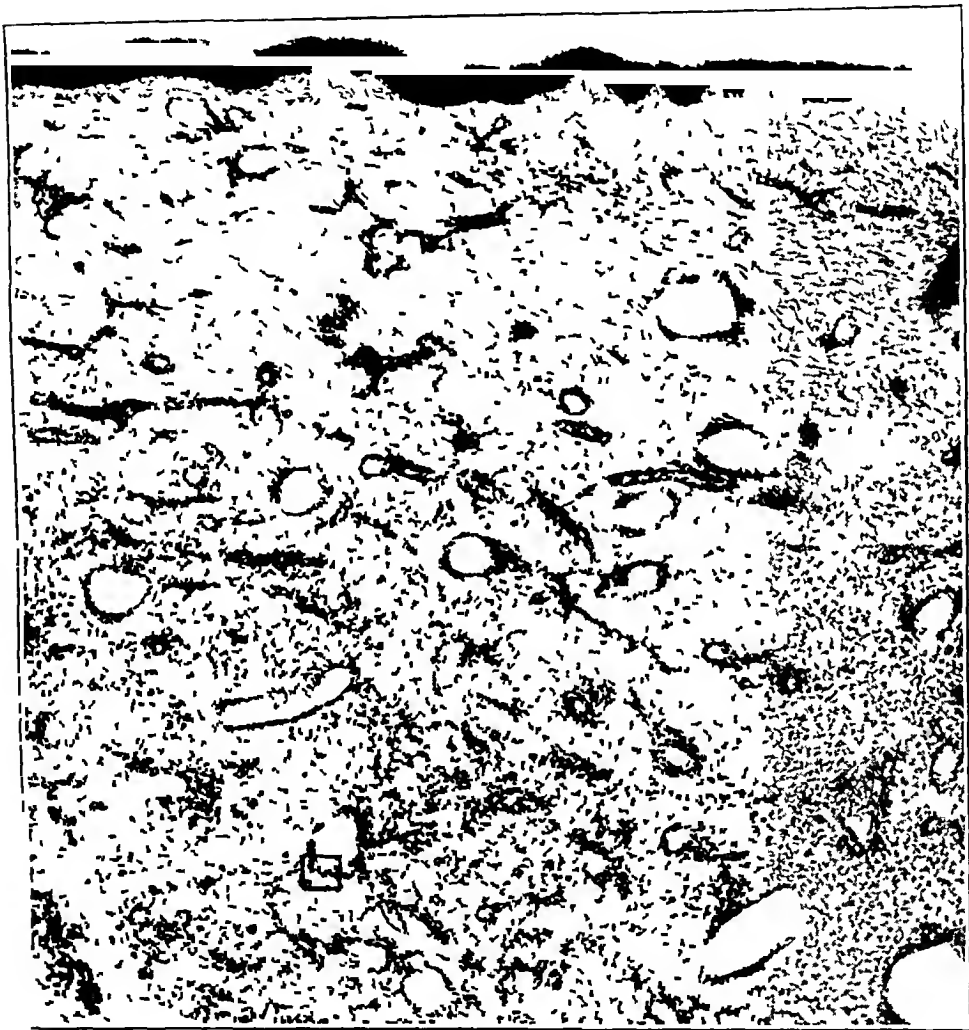


Fig 11—Myxosarcoma of the nose and nasopharynx in a boy, aged 16, complete nasal obstruction for one year, no improvement following radium treatment, section comes from the posterior end of the inferior turbinate, area marked is shown in Figure 12

**Examination**—The Wassermann reaction was negative. The growth filled the entire nasopharynx and both sides of the nose. There was involvement of the right antrum nine months after the onset of symptoms.

**Diagnosis**—The microscopic diagnosis was myxosarcoma (Figs 11 and 12).

**Treatment**—Between June 13, 1919, and Aug 26, 1919, the patient received three heavy irradiations at a distance of from 5 to 6 inches. The total radiation

amounted to 46 500 mc hours of gamma radiation applied intensively during the time that it was given

*Course*—August, 1919, there was no improvement The growth extended under the malar arch on the right The patient died

*CASE 30—History*—A colored man, aged 49, was admitted in April, 1918, complaining of nasal obstruction on the right, headaches and nosebleed, the onset of which had occurred six months previously

*Examination*—The Wassermann reaction was negative The growth arose from the lateral nasal wall on the right The left nostril and the nasopharynx

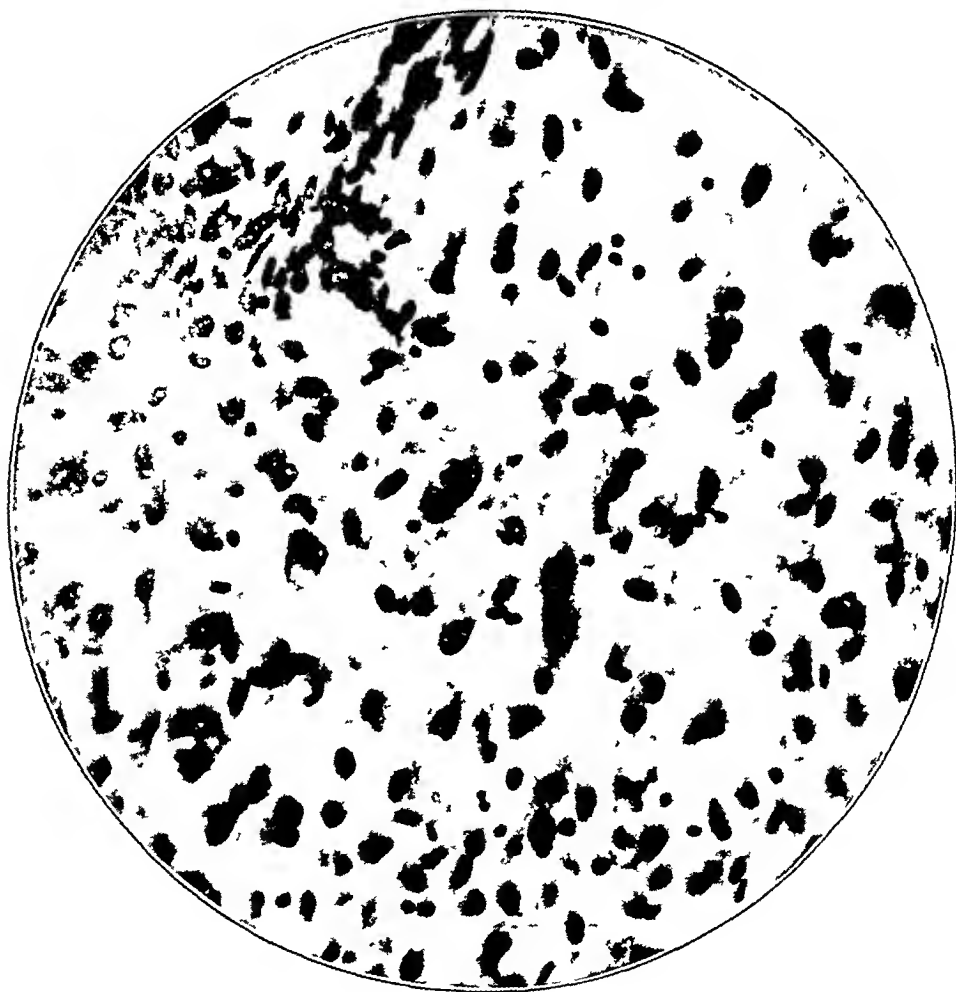


Fig 12—Portion of specimen shown in Figure 11, illustrating the type of tumor cell This patient died Compare with Figure 10

were not involved The nose bled easily There were no enlarged glands in the neck, and no ear symptoms The roentgen ray revealed clouding of the right antrum, suggesting growth

*Diagnosis*—The microscopic diagnosis was sarcoma

*Treatment*—The patient was given very intensive irradiation between April 30, 1918 and Dec 5, 1919 The external irradiations totaled 31,300 mc hours of gamma radiation at a distance of 4 inches over the right and left sides of the

face In addition to this, he received a total of 71 mc of radium emanation in glass capillary tubes, in amounts varying from 3 to 7 mc, all implanted directly into the nasopharynx

*Course*—April 27, 1919, there was no improvement in the breathing space

September, 1919, there was still a large growth in the right nostril, and bleeding was less frequent

February, 1920, the right nostril was entirely occluded

CASE 31—*History*—A white woman, aged 47, was admitted in April, 1915, complaining of enlarged glands in the neck and difficulty in breathing, even

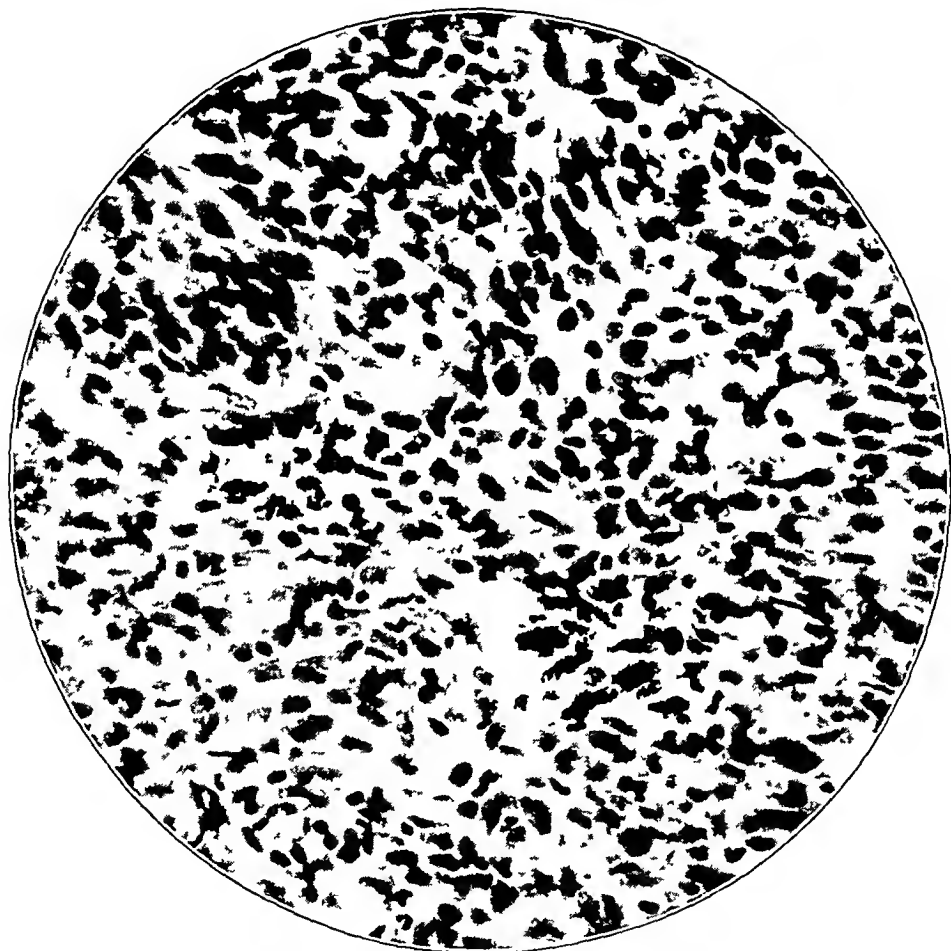


Fig 13—Sarcoma of the nasopharynx in a man, aged 49, history of nasal obstruction, pain and frequent hemorrhages Radium did not cause the growth to disappear, but the symptoms are relieved and the growth has not advanced during the two years of observation

through the mouth The onset of symptoms had occurred seven months before admission

*Examination*—There were metastatic glands in the neck on both sides The entire soft palate was pushed forward by a large soft reddish growth There was no general glandular enlargement, no bleeding and no ear symptoms A roentgenogram of the chest revealed no definite changes

*Diagnosis*—The microscopic diagnosis was round-cell sarcoma

*Treatment*—Between April 10, 1915, and June 20, 1916, the patient was given very extensive external irradiation, 45,000 mg hours of gamma radiation being employed at a distance of 2 inches

*Course*—April 16, 1915 The first radium treatment was given five days previously

May, 1915, the growth had decreased to one-third its original size There was no growth in the throat There was one large mass of glands in the right side of the neck, measuring 5 by 5 cm

August, 1915, the patient felt better There was no difficulty in breathing One small gland was felt in the neck She had gained in weight

September, 1915, a large gland was present on each side of the neck

Oct 2, 1915, the gland on the right side of the neck had disappeared The one on the left was smaller

October 23, the gland in the right axilla was enlarged

January, 1916, there was general glandular enlargement, a mass in the upper part of the abdomen on the left, and a recurrence in the throat

April 14, 1916, the patient died, having been confined to her bed for the previous year The glands of the neck had broken down

*CASE 32—History*—A colored man, aged 48, was admitted in March, 1915, complaining of symptoms that had occurred seven months previously The first symptom was obstruction of the tear duct on the right, then exophthalmos and nasal obstruction on the right There had been no pain

*Examination*—The Wassermann reaction was negative The growth had apparently originated in the ethmoidal region on the right, later involving the nasopharynx There had been no pain during the first year of the trouble There were no palpably enlarged glands at the time of examination There was no bleeding at any time

*Diagnosis*—The microscopic diagnosis was sarcoma

*Treatment*—Oct 1, 1920, the patient received intensive irradiation, 37,000 mc hours of gamma radiation being employed at a distance of 2 inches Light radiation was also applied directly to the growth by means of a sound inserted through the nostril

*Course*—May, 1915 the growth had markedly decreased in size Exophthalmos was less marked The patient could now breathe easily through the nose, although it still contained a visible growth

June, 1915, there was no further improvement

September, 1915, there were large masses of metastatic glands on both sides of the neck The nasopharynx and the left side of the nose were involved The general condition was worse

June, 1916, the patient died of intracranial involvement, terminating in meningitis

*CASE 33—History*—A white boy, aged 19, was admitted in May, 1918, complaining of obstruction to breathing through the nose as the earliest symptom, one year previously A large mass of "adenoids" had been removed in August, 1917, but was not examined microscopically Since this operation frequent and severe hemorrhages had been the most prominent symptom In April, 1918, the growth in the nasopharynx was again removed, after a preliminary tracheotomy Recurrence had been rapid

*Examination*—The Wassermann reaction was negative Both sides of the nose posteriorly and the entire nasopharynx were filled with growth The soft palate was pushed forward by the growth

*Diagnosis*—The microscopic diagnosis was myxosarcoma

*Treatment*—The patient received intensive treatment between May 1, 1918, and Dec 6, 1920 During this time, 16,950 mc hours of gamma radiation was applied directly to the growth at a distance of from 1 to 5 inches, 37 mc was implanted in the growth

*Course*—July, 1918, an emanation point was buried in the nasopharynx

September, 1918, the growth was steadily diminishing in size Hemorrhages were less frequent

January, 1919, the growth had almost disappeared from both sides of the nose There were remains of the growth in the nasopharynx The patient could breathe through the nose

March 1919, the growth remained about the same in the nasopharynx The general health was excellent Radium was applied directly to the tumor through each nostril and through the mouth This treatment was followed within a few days by a severe hemorrhage

June, 1919, the growth in the nasopharynx was much larger and had recurred in the left side of the nose There was profuse bleeding after each treatment

June, 1920, the growth was much smaller than it had been a year previously The patient breathed well through the nose Bleeding was much less frequent

April 23, 1921, the patient was seen by Dr Winslow, who found no evidence of trouble Dr William Neill, Jr, in his examination, concurred with Dr Winslow He pronounced it a perfect result, and, in spite of the heavy implantation and direct application, there was no damage to the soft palate or septum

May 11, 1922, the patient felt perfectly well Examination of the nasopharynx by Dr C F Burnam revealed a perfectly normal condition

#### CARCINOMA OF THE NASOPHARYNX

CASE 34—*History*—A white man, aged 23, was admitted, Nov 30, 1914, complaining of pain in the throat and swelling of the glands of the neck, nasal obstruction on the left, headache and nosebleed, and fixation of the jaw These symptoms had been of four months' duration

*Examination*—The Wassermann reaction was negative The obstruction of the posterior part of the nose on the left was due to the growth There were no ear symptoms There were metastatic glands on both sides of the neck

*Diagnosis*—The microscopic diagnosis was carcinoma

*Treatment*—The patient received a moderate single radium treatment, Dec 6, 1914, 3,800 mc hours of gamma radiation being employed at a distance of 1 inch There were no other treatments and the radium treatment in this case can hardly be considered

*Course*—There were no subsequent notes

CASE 35—*History*—A white woman, aged 42, was admitted in February, 1919 complaining of sore throat, bleeding from the throat and enlarged glands of the neck on both sides The glands of the neck on the right were as large as an orange, and those on the left were visibly enlarged



*Examination*—The Wassermann reaction was negative. The growth arose from the vault and the right lateral wall of the nasopharynx. The nose was not involved. There was no obstruction to breathing and no ear symptoms. There were huge glands in the neck.

*Diagnosis*—The microscopic diagnosis was carcinoma.

*Treatment*—Between Jan 17 and Sept 11, 1920, the patient received very intense irradiation, 22,900 mc hours of gamma radiation, at a distance of 2 inches, being employed over the right side of the face and neck. Fourteen mc of radium emanation was also implanted directly into the involved glands in the neck and 500 mc of gamma radiation was implanted directly in the nasopharynx. In October, 1919, a portion of an enlarged gland of the neck on the left was removed for microscopic examination. Nov 20, 1919, the glands of the neck on the right were excised. Operation for excision of the glands on the left was refused. No operation was performed on the nasopharynx.

*Course*—January, 1920, the general condition was excellent. There was a recurrence in the glands high up on the right side of the neck. Radium was implanted in these glands in June, 1920. The glands of the neck were not palpably enlarged. The patient was gaining in weight.

October, 1920, examination revealed no evidence of growth in the nasopharynx. The patient was breathing freely.

October, 1921, the patient died with involvement of the mediastinum and esophagus. There was no recurrence in the nasopharynx.

*CASE 36—History*—A white girl, aged 19, was admitted in August, 1919, complaining of enlarged glands of the neck on the left, inability to open the mouth and bleeding from the mouth. The symptoms had been present for three months.

*Examination*—The Wassermann reaction was negative. The growth arose in the nasopharynx on the left. The nose was not involved. There was no obstruction, no bleeding and no ear symptoms.

*Diagnosis*—The microscopic diagnosis was carcinoma.

*Treatment*—The patient would not consent to radium treatment for four months after the diagnosis had been made.

Dec 2, 1919, the patient received 200 mc hours of gamma radiation applied directly against the growth in the nasopharynx, also two external irradiations, Dec 7 and Dec 14, 1919, totaling 6,800 mc hours, centered over the glands of the neck. This was very mild irradiation.

*Course*—July, 1920, cachexia had developed, and the patient was confined to bed. There were frequent hemorrhages from the throat.

*CASE 37—History*—A white woman, aged 33, was admitted, April 18, 1917, complaining of headache, bleeding from the throat, enlarged glands of the neck, fixation of the jaw and loss of the sense of smell. The patient was also suffering from agitated depression, for which she had been admitted to the Phipps Psychiatric Clinic. The adenoids had been removed in September, 1916, because of bleeding. The tonsils had been removed, March 19, because of cervical adenitis. The tissue was not examined microscopically. Examination by Dr Harvey Cushing for brain tumor, in April, 1916, was negative.

*Examination*—The Wassermann reaction was negative. There were metastatic glands on both sides of the neck, diplopia, but no otitis media.

*Diagnosis*—The microscopic examination of tissue removed from the nasopharynx was carcinoma

*Treatment*—Sept 22, Oct 22 and Nov 14, 1917, a radium treatment was applied to the glands of the neck Oct 4 and Nov 24, 1917, an external treatment was given October, 1917, 600 mg of radium emanation was applied to the right side of the nasopharynx for ten minutes and to the left side for five minutes November, 1917, 850 mg was applied for five minutes each (1) over the anterior portion of the left sphenoid, (2) over a portion of the right sphenoid, (3) and (4) against each pharyngeal wall

*Course*—Dec 22, 1917, the patient died of intracranial involvement

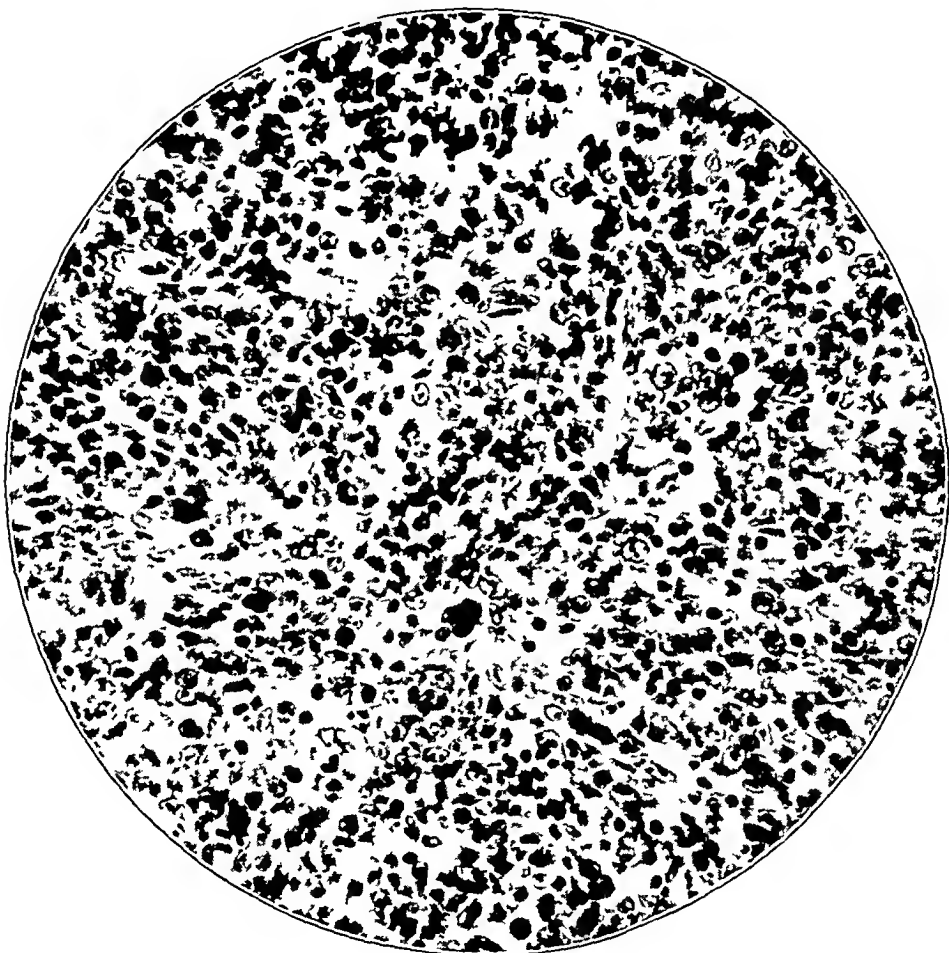


Fig 14—Carcinoma of the nasopharynx in a man, aged 25, symptoms fixation of jaw, enlarged glands of neck, involvement of trigeminus, hemorrhages from mouth and nose, temporary decrease in size of growth and relief of pain after irradiation

CASE 38—*History*—A white man, aged 25, was admitted in February, 1918, complaining of deafness in the right ear, suppurative otitis media on both sides, sore throat for six months inability to open mouth, enlargement of the glands of the neck on both sides which were hard and firmly fixed, involvement of the fifth nerve and pain

*Examination*—The Wassermann reaction was negative. There was no difficulty experienced in breathing through the nose. The growth bled easily when touched, there were no spontaneous hemorrhages. When first seen, the growth involved the anterior wall of the sphenoidal sinuses, the posterior part of the septum and the entire region of the orifice of the right eustachian tube.

*Diagnosis*—The microscopic diagnosis of a piece of tissue removed from the nasopharynx was carcinoma (Fig 14).

*Treatment*—From Feb 9, 1918, to Aug 8, 1919, the patient received intensive radium treatment, consisting of 89,200 mc hours of gamma radiation at a distance of from 3 to 5 inches applied externally, as well as 666 mc hours applied directly to the surface of the growth, and two capillary tubes, each containing 5 mc of radium emanation, implanted in the growth.

*Course*—April, 1918, two months after the radium treatment was begun the growth in the nasopharynx and the metastatic glands in the neck had decreased to about one-tenth their previous size. The jaw remained fixed, and the patient still suffered pain.

July, 1919, there was no evidence of growth in the nose, throat or nasopharynx. The glands of the neck were slightly larger than they were one year previously. There was no evidence of metastasis elsewhere. The general condition was bad. The patient was cachectic, the jaw was still fixed, and the pain was much reduced.

**CASE 39—History**—A white man, aged 57, was admitted in September, 1917 complaining of enlarged glands of the neck on both sides, obstruction and pain in the right ear, a constant salty taste, and inability to open the mouth. The first symptom had occurred two months previously.

*Examination*—The Wassermann reaction was negative. The growth had originated under the mucous membrane on the right side of the nasopharynx. There was involvement of the fifth nerve.

*Diagnosis*—The microscopic diagnosis, made from a specimen of the gland of the neck removed for diagnosis, was squamous-cell carcinoma.

*Treatment*—The patient received intensive external irradiation from Oct 31, 1917, to April 1, 1918, a total of 58,900 mc hours being given at a distance of from 2 to 4 inches over the right side of the face and the cervical glands.

*Course*—The patient died in September, 1918, of cachexia.

**CASE 40—History**—A white man, aged 42, was admitted, Feb 24, 1913, complaining of pain and impairment of hearing in both ears, suppurative otitis media in the left ear, of ten months' duration, enlarged glands of the neck, headaches, hemorrhages from the mouth and nose, diplopia, loss of the sense of smell and taste, and metastases under the zygoma on the left. The onset of symptoms had occurred eighteen months before admission.

*Examination*—The Wassermann reaction was negative. There was no involvement of the nose. The growth occupied the entire nasopharynx. There was an ulcerated area near the orifice of the eustachian tube on the left.

*Diagnosis*—The microscopic diagnosis was carcinoma.

*Treatment*—The gland of the neck was removed for microscopic diagnosis. No radium treatment was employed. Treatment was given with Coley's fluid for five weeks in New York by Dr. Coley, with transient decrease in size of the metastatic gland.

*Course*—April 1913, the general condition was much worse. The patient was having severe headaches and attacks of nosebleed. He died May 26, 1913.

CASE 41—*History*—A colored boy, aged 11, was admitted in November, 1919, complaining of sore throat, headaches and night sweats until October, 1918, when the tonsils and adenoids were removed. Swelling occurred on the right side of the neck shortly after this. Headache and pain in the neck increased, and the jaw became fixed. The symptoms had been present for seventeen months. The growth possibly originated following the removal of the adenoids and tonsils.

*Examination*—The Wassermann reaction was negative. There were enlarged, hard glands in the neck on both sides.

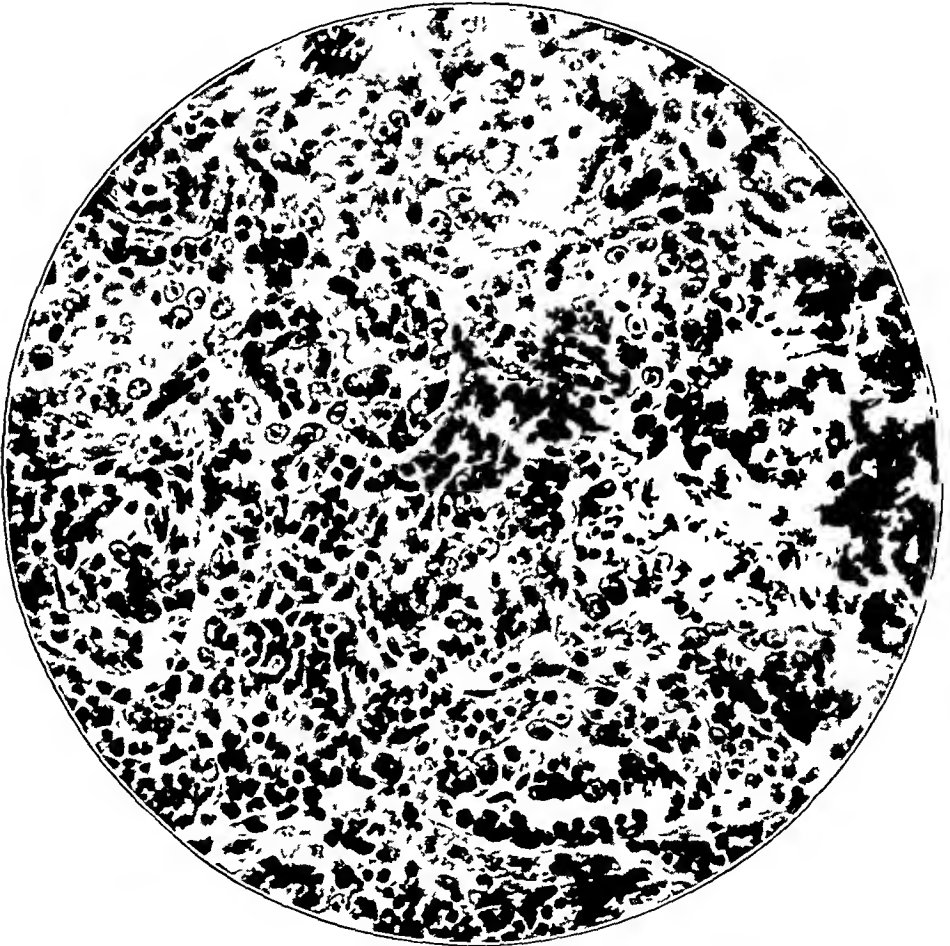


Fig 15—Primary carcinoma of nasopharynx with metastatic glands of neck in a boy, aged 11 years, not treated

*Diagnosis*—The microscopic diagnosis made from a piece of tumor removed from the nasopharynx and also from a gland removed for diagnosis was carcinoma.

*Treatment*—No radium treatment was given in this case on account of the extensive involvement. Operation was not advised and the patient was discharged untreated.

*Course*—There was no subsequent note.

**CASE 42—History**—A white man, aged 50, was admitted in October, 1914, complaining of an obstruction in the eustachian tube on the left, following a cold. He had had a blood stained sputum since the onset and severe pain in the left side of the head. There was paresis of the soft palate on the left but no metastasis to the glands of the neck. He had diplopia. These symptoms had begun nine months previously.

**Examination**—The Wassermann reaction was negative. The onset of the ear symptoms followed a cold. The ear had been treated by inflation, and later the nasal septum had been straightened. The growth in the nasopharynx was not recognized for nine months, although the patient had a bloody discharge from the onset. On admission there was intracranial involvement, but there were no metastatic glands of the neck and no fixation of the jaw.

**Diagnosis**—Tissue removed from the nasopharynx for microscopic examination revealed carcinoma.

**Treatment**—The patient was first seen here, Oct 12, 1914, and was given very little irradiation on that day. Dec 12, 1914, he was given 5,733 mc hours of gamma radiation at a distance of 2 inches directed on the left side of the face and neck. The treatment in this case was given only with the idea of palliating pain and was not intensive enough to effect any real change in the growth, as we felt that the disease was so extensive that treatment was useless.

**Course**—The patient died one month after the onset of the ear symptoms, with orbital and intracranial involvement.

**CASE 43—History**—A white man, aged 31, was admitted in September, 1917, complaining of exophthalmos on the right, and an obstruction of the right side of the nose, with bleeding, the onset of which had occurred four months previously. There were large, hard, firmly fixed glands in the neck on the right.

**Examination**—The Wassermann reaction was negative. The point of origin was probably in the posterior part of the nose, the orbit being involved at an early stage.

**Diagnosis**—The microscopic diagnosis was carcinoma.

**Treatment**—The patient was treated from Sept 16, 1917, to Nov 25, 1917. During this time, he received several mild treatments, but the total was only 8,100 mc hours of gamma radiation employed at a distance of 3 inches.

**Course**—The patient died ten months after the onset. There was an orbital involvement on the right, with loss of vision, and also terminal intracranial involvement. This patient received local treatment for nasal obstruction for four months before coming to the Johns Hopkins Dispensary.

**CASE 44—History**—A white man, aged 54, was admitted in June, 1920. His earliest complaint had been a nasal obstruction on the right, and an obstruction of the right eustachian tube, with bleeding, three years previously. He had had a nasal operation two years previously, and a large amount of tissue was said to have been removed, followed by profuse bleeding.

**Examination**—The Wassermann reaction was negative. The growth involved the right side of the nasopharynx and the right nostril. No metastatic glands of the neck were found and no infection of the ears. There had been a history of difficulty in breathing through the nose for seven years.

**Diagnosis**—Tissue removed from the nose for microscopic examination revealed carcinoma.

**Treatment**—The patient received three radium treatments, June 19, June 23, and June 28, 1920, at a distance of 3 inches, centered over the right and left

sides of the face, a total of 21,200 mc hours of gamma radiation being employed. There was no improvement after these treatments, and, when the patient was seen, Sept 3, 1920, the growth had increased, and both nostrils and the nasopharynx were blocked with the growth. He was having severe pain in the back of the head. No further treatment was given.



Fig 16—Carcinoma of right nostril and nasopharynx in a man, aged 54, no improvement of any kind following radium treatment

*Course*—In December, 1920, the patient wrote that he was having repeated hemorrhages from the nose and throat, and that the glands of the neck were rapidly increasing in size.

*CASE 45—History*—A colored boy, aged 19, was admitted in May, 1915. His earliest symptom had been sore throat and an enlarged gland in the neck with pain in the right side of the face and eye, for two months. He had had

hemorrhages from the nose and an impairment of hearing on the right. Fixation of the jaw appeared after the onset.

*Examination*—The Wassermann reaction was negative. There were hard movable glands on both sides of the neck, with a slight enlargement of the glands of the axillae and groins. The spleen was not enlarged. A roentgenogram of the lungs was negative. The differential blood count was normal: white blood cells, 13,700, hemoglobin, 87 per cent. He had lost 45 pounds during the past two months. There was no elevation of temperature.

*Diagnosis*—The microscopic diagnosis was carcinoma, probably arising from the basal layer of the ciliated epithelium in the nasopharynx.

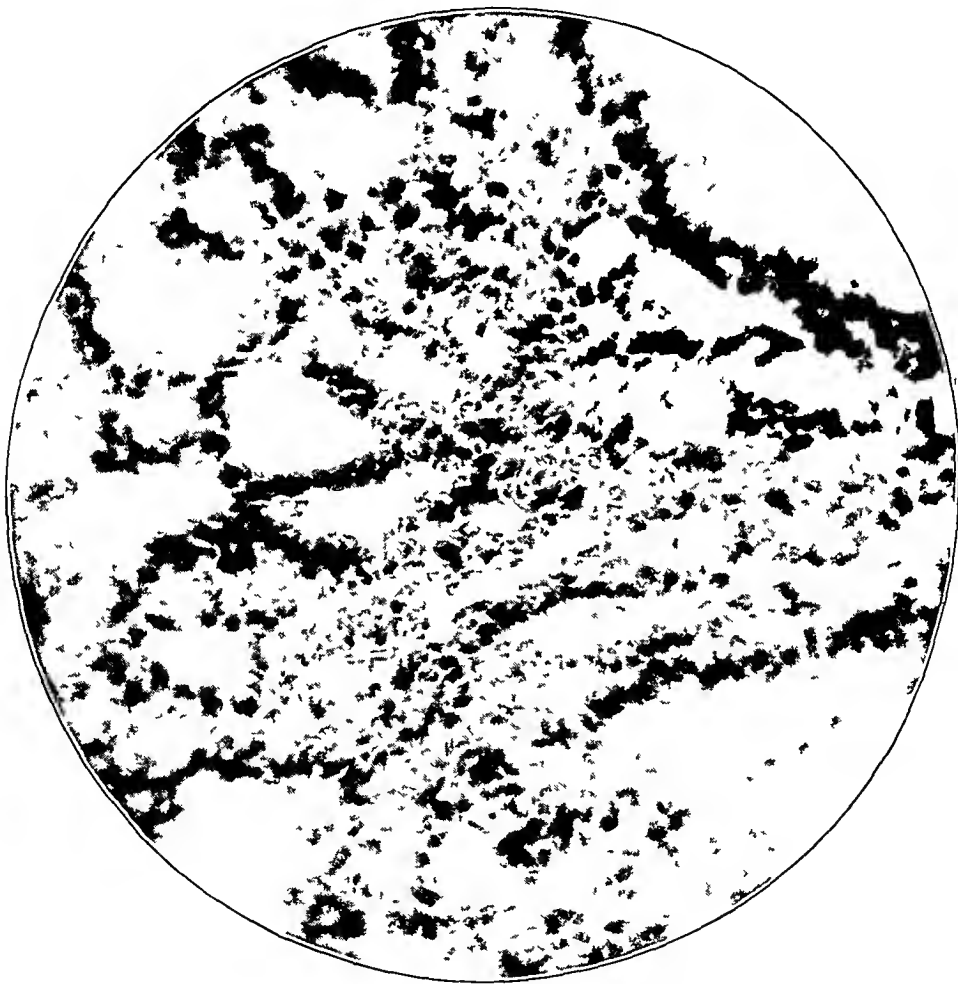


Fig 17—A higher magnification of Figure 16

*Treatment*—The patient received two heavy radium treatments. (1) Aug 3, 1915, 24,900 mc hours of gamma radiation was employed at a distance of 3 inches, distributed over the right and left cheeks and over the right and left sides of the neck. (2) Oct 14, 1915, the treatment was employed directly on the tumor in the nasopharynx for one and one-half hours, with 100 mg of radium bromid—screened with 2 mm of brass and a thin layer of rubber. Nov 14, 1915, he received 3,500 mc hours of gamma radiation at a distance of 1 inch directed over the enlarged glands on the right side of the neck.



*Course*—This patient died soon after leaving the hospital. No necropsy was performed.

*CASE 46—History*—A colored girl, aged 11, was admitted in November, 1919. Pain and discharge from the right ear had been the first and the only symptoms for one month. There had been stiffness of the jaw and bleeding from the nose and mouth during the previous five months.



Fig 18—Carcinoma of the nasopharynx in a girl, aged 11 years, not treated

*Examination*—The Wassermann reaction was negative. She was unable to separate the teeth more than 1 cm and could take only liquid food. A hard irregular tumor was found in the nasopharynx, occluding the right eustachian tube. It bled easily when touched with a probe. The hemoglobin was 37 per



cent She was given a transfusion The glands were enlarged at the angles of the jaws on both sides, but not elsewhere in the body The nose appeared normal A roentgenogram of the chest was negative

*Diagnosis*—A piece of tissue removed from the nasopharynx for microscopic diagnosis revealed carcinoma (Fig 18)

*Treatment*—The growth in this case was too advanced for operation, or irradiation One glass capillary point, containing  $4\frac{1}{2}$  mc of radium emanation,



Fig 19—Large metastatic glands in neck The only symptom of the primary carcinoma in the nasopharynx was bleeding from the mouth, excision of the larger glands and implantation of radium in the smaller ones resulted in an apparent cure for eighteen months, death due to recurrence in mediastinum and esophagus

was implanted directly into the growth, followed by a very severe hemorrhage four days later

*Course*—There was no report, but the child probably died very soon after leaving the hospital

**CASE 47—History**—A white man, aged 42 was admitted in February, 1913 There had been a history of acute sinusitis, two or three times a year, for the past eight or ten years The first symptoms had been pain, deafness a dis-



Fig 20—Myxosarcoma involving both sides of nose, nasopharynx and right antrum, no improvement after radium treatment, microscopic appearance shown in Figures 11 and 12



Fig 21—Spindle-cell sarcoma in a child, aged 4 years, first fourteen radium treatments caused the growth to disappear macroscopically, but had no effect on the recurrence

charge from the left ear, ten months previously. He had had a headache on the left side for ten months, and enlarged glands of the posterior triangle on the left for eight months, with a loss of 40 pounds in weight.

*Examination*—The Wassermann reaction was negative. This case was diagnosed as syphilis, and for six months the patient had had mercury and iodids with no benefit. A piece of tumor in the nasopharynx had been removed for diagnosis, six weeks previously. Since that time, hemorrhages had been frequent. He had a low-grade choked disk, paralysis of the sixth nerve on the left, involvement of the second and the third divisions of the fifth nerve on the left. There was palsy of the soft palate on the left.

*Diagnosis*—The microscopic diagnosis was carcinoma.

*Treatment*—The patient was referred to Dr. Coley in New York, who treated him with Coley's fluid for five weeks. The glands of the neck decreased in size, but the general condition became worse. He then went to St. Louis and received injections of colloidal copper, administered by Dr. Loeb, with no benefit. No radium treatment was given in this case.

*Course*—The patient died in May, 1913, about one year after the onset of the ear symptom.

**CASE 48—History**—A white woman, aged 55, was admitted in April, 1912. The first symptom had been pain in the left side of the head, which had been constant for seven months. There had been pain in the left ear and deafness for six months, but no discharge. She had not complained of nasal obstruction.

*Examination*—The Wassermann reaction was negative. There were no metastases to the glands of the neck. She had had cerebrospinal rhinorrhea for four months. A low-grade choked disk was demonstrated, but no involvement of the orbit or the trigeminus. She had palsy of the soft palate on the left. The growth occupied the entire nasopharynx and the posterior half of the nose on the left.

*Diagnosis*—No tissue was removed because of the cerebrospinal leakage through the nose.

*Treatment*—No treatment was advised on account of the intracranial involvement.

*Course*—There was no report, but the patient probably died soon after leaving the hospital.

**CASE 49—History**—A colored man, aged 29, was admitted in April, 1911. His first symptom had been pain in the throat, which for three months was ascribed to bad teeth. There had been enlarged glands near the angle of the jaw on the right, which had been noticed four months previously. He had not complained of nasal obstruction, and he had been unable to open the mouth for two months.

*Examination*—The Wassermann reaction was negative. Metastatic glands of the neck appeared first on the right, and then on the left. He had a fixation of the jaw. There were large mucous polyps in the right side of the nose, which bled profusely when removed. There was no intracranial involvement. The differential blood count was normal. The growth had apparently originated in the nasopharynx and the posterior naris on the right.

*Diagnosis*—The microscopic diagnosis was carcinoma.

*Treatment*—The growth in this case was too far advanced for operation or irradiation.

*Course*—The patient died, Aug. 8, 1911, at Mercy Hospital, Philadelphia, a little less than a year after onset of the first symptom.

# STUDIES IN EXHAUSTION IV PHYSICAL TRAUMA

G W CRILE, M D

CLEVELAND

As stated in the first of these reports,<sup>1</sup> these studies in exhaustion were initiated by an investigation of the cause of surgical shock. Chronologically, therefore, the publication of this article should have preceded that of the studies on insomnia, exertion and emotion.<sup>2</sup> It seemed a more logical sequence, however, to offer evidence of the conditions demonstrated in exhaustion or shock due to extreme degrees of intensity of the factors of normal consciousness before considering exhaustion due to pathologic conditions.

Perhaps no other subject in surgical literature presents so extensive a bibliography as "surgical shock," but the space at my disposal for this report prohibits any adequate review of this literature, or discussion of the various theories of the causation of shock, such as I have offered in previous publications.<sup>3</sup>

These studies, like those of many other investigators, were undertaken to investigate the essential nature and causation of shock produced by physical trauma. These studies, which are still in progress and have embraced studies of exhaustion due to many different causes, have included observations of the variations in blood pressure produced by physical injury of various organs and tissues, histologic studies of various organs and tissues of animals in shock due to physical injury, investigations of the hydrogen-ion concentration of the blood, estimations of the alkali reserve, measurements of the electrical conductivity of various organs and tissues, and the direct measurement of variations in the temperature of the brain and the liver.

By these various methods, both the immediate and the late effects of physical injury have been studied. Complete reports of some of these researches and summaries of others have been given in previous publications. It is my purpose here to bring together the findings in these studies to the present time, in order that they may be properly recorded and correlated.

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1 Crile G W Studies in Exhaustion An Experimental Research, I Insomnia, Arch Surg 2 196-220 (March) 1921

2 Crile G W Studies in Exhaustion II Exertion Arch Surg 3 116-131 (Jul) 1921 Studies in Exhaustion III Emotion ibid 4 130-153 (Jan) 1922

3 Crile G W Reference Handbook of Medical Sciences 7 728-734 1917  
A Physical Interpretation of Shock Exhaustion and Restoration New York, Oxford University Press 1921 Mechanism of Shock and Exhaustion J A M 76 149-155 1921

## A BLOOD PRESSURE CHANGES PRODUCED BY PHYSICAL TRAUMA

Since the experimental details of these studies have been presented in detail elsewhere,<sup>4</sup> and a complete summary has been made in a recently published volume,<sup>5</sup> I shall include here only the following general conclusions drawn from these initial studies

1 There is a quantitative relationship between physical trauma and shock which may be estimated by blood pressure variations, that is, the degree of shock (exhaustion) varies directly with the amount of tissue

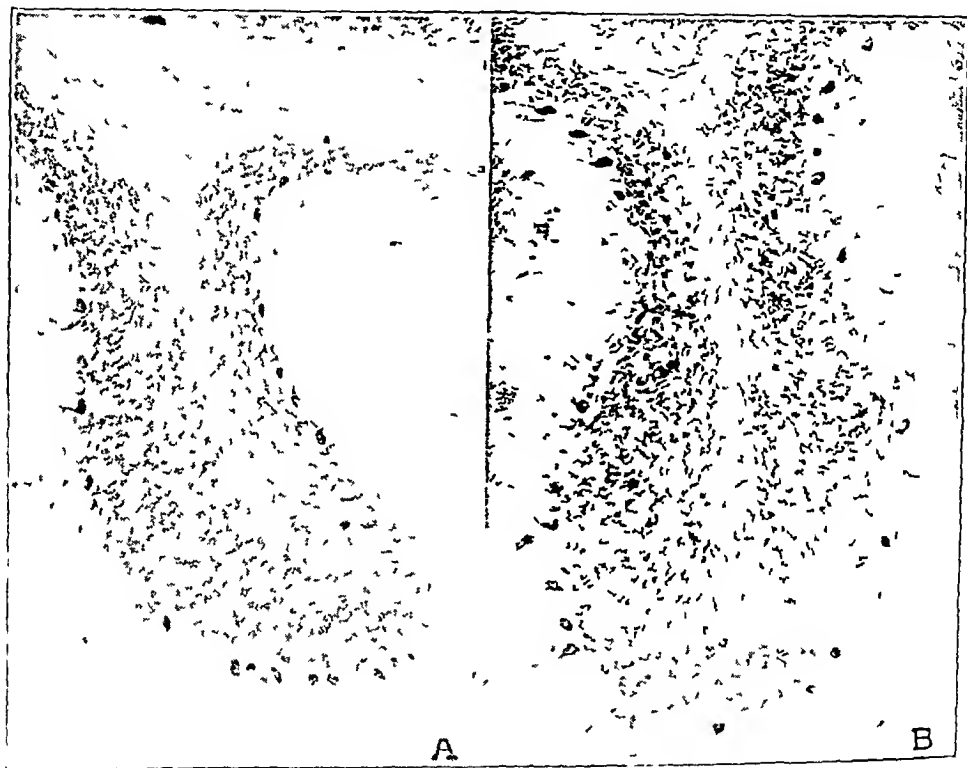


Fig 1—Incipient effect of physical trauma upon the brain cells *A*, section of cerebellum of a normal dog, *B*, section of cerebellum of a dog after severe abdominal trauma for five minutes (reduced from photomicrographs,  $\times 120$ ) The hyperchromatism of the Purkinje cells in *B* may be noted

injured, with the intensity of the injuring stimulus, with the number of the injuring impacts

2 The degree of shock produced by physical trauma bears an inverse relation to the phylogenetic protection of the injured tissues, that is,

4 Crile, G W Surgical Shock, 1897, Certain Problems Relating to Surgical Operations, 1901, Blood Pressure in Surgery, 1903

5 Crile, G W A Physical Interpretation of Shock, Exhaustion and Restoration, Footnote 3, pp 6-40

the injury of tissues and organs which have been protected throughout the evolution of the organism, e g , the brain, the lungs, etc , produces but little shock as compared with injury of such exposed regions as the abdomen, the skin and the extremities Injury of the deep, protected tissues produces collapse rather than shock

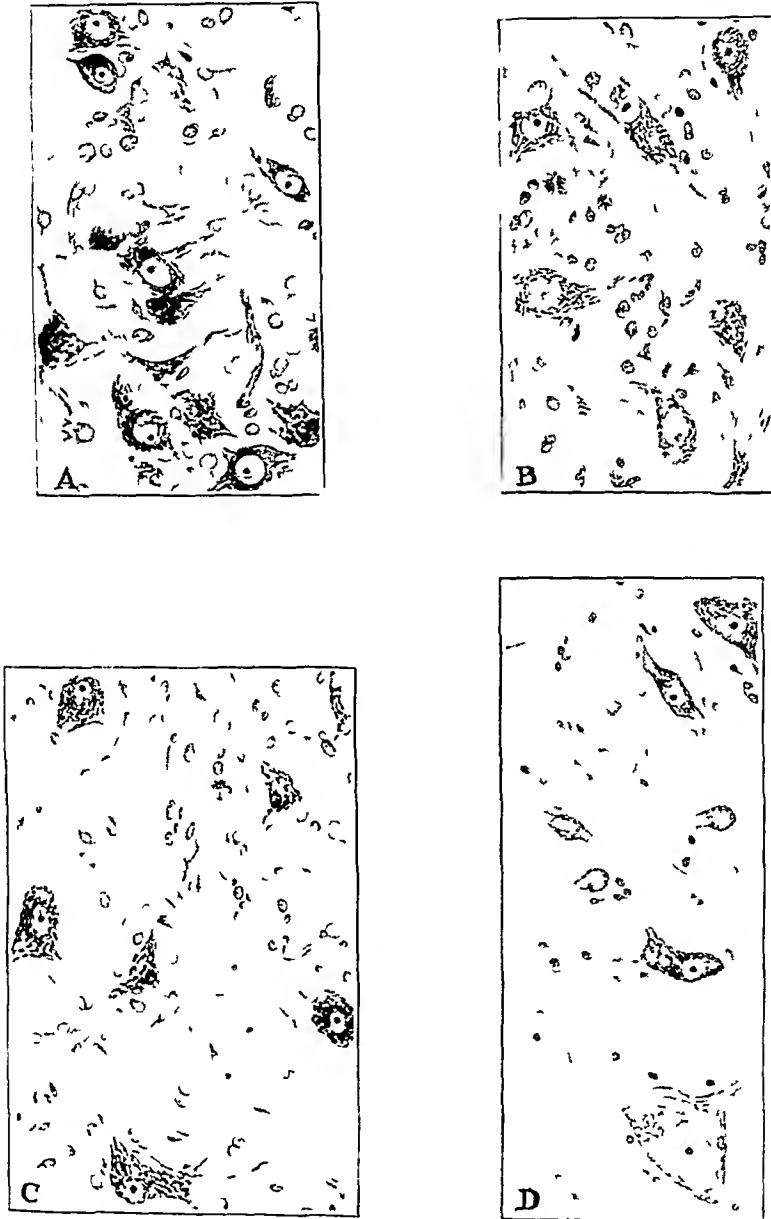


Fig 2—Effect of physical trauma on the medulla and the spinal cord  
 A section of normal medulla B section of medulla after physical trauma,  
 C section of anterior horn of normal spinal cord in cervical region D, section of  
 anterior horn of spinal cord in cervical region after physical trauma (from  
 camera lucida drawings)

- 3 The degree of shock bears a direct relation to the nerve supply of the injured tissue
- 4 Exhaustion of the vasomotor mechanism is present in shock but is not the only factor in its production
- 5 Shock from injury of any tissue can be prevented by blocking the nerve supply of that tissue by a local anesthetic

B THE EFFECT OF PHYSICAL TRAUMA ON THE  
CONSTITUENTS OF THE BLOOD

In collaboration with Drs F W Hitchings, C H Lenhart and A B Eisenbrey, a series of experiments were performed to determine whether

Per Cent	10	20	30	40	50	60	70	80
<u>Active</u>	Ether							
	Nitrous Oxid							
	Normal							
<u>Fatigued</u>	Ether							
	Nitrous Oxid							
	Normal							
<u>Exhausted</u>	Ether							
	Nitrous Oxid							
	Normal							

Fig 3—Comparison of the effect on the brain cells of abdominal trauma under ether anesthesia with that of like trauma under nitrous oxid anesthesia (differential Purkinje cell counts)

or not the number of red or of white corpuscles or the amount of hemoglobin was affected by physical trauma

After a preliminary examination of the blood, each dog was subjected to severe intestinal manipulations, and blood examinations were made at successive intervals of about an hour. The blood was taken from the peripheral circulation, usually from the tip of the nose.

The findings in these experiments (Table 1) demonstrate that, in this limited group at least, abdominal trauma produced no notable

change in the blood, excepting in two instances in which there was a marked decrease in the number of white cells

### C HISTOLOGIC STUDIES

If the vasomotor center was fatigued in shock, as had been demonstrated by the researches described above, then it seemed reasonable to suppose that other portions of the brain would be fatigued also, and, that, if so, the resultant functional alterations of the brain cells would be accompanied by structural changes

TABLE 1—EFFECT OF ABDOMINAL TRAUMA ON THE CONSTITUENTS OF THE BLOOD

	Blood Pressure, Mm Hg	Red Cells	White Cells	Hemoglobin, per Cent
Dog 1				
Before trauma	110	7,500,000	8,000	100
After trauma				
Count 1	62	6,400,000	16,000	100
Count 2	60	7,660,000	11,500	98
Dog 2				
Before trauma	114	8,440,000	23,800	100
After trauma				
Count 1	105	8,304,000	12,400	100
Count 2	92	8,944,000	9,100	100
Count 3	88	8,933,000	8,200	100
Dog 3				
Before trauma	144	6,184,000	25,000	100
After trauma				
Count 1	91	6,608,000	6,900	200
Count 2	40	6,963,000	6,400	100
Dog 4				
Before trauma	128	5,920,000	23,600	100
After trauma				
Count 1	92	6,240,000	10,400	100
Count 2	60	5,216,000	14,000	100
Count 3	84	7,200,000	25,000	100

Pursuant to this assumption, in 1900, in collaboration with Dr D H Dolley, histologic studies of the brain after traumatic shock were initiated. These studies were continued in collaboration with Dr J B Austin and Dr F W Hitchings and were extended to include other organs and tissues.

#### THE EFFECT OF PHYSICAL TRAUMA ON THE CELLS OF THE CENTRAL NERVOUS SYSTEM

Two major groups of experiments were performed, one in which the animals were under ether anesthesia, and one in which trauma, equal to that employed in the first group, was applied to animals under nitrous oxide anesthesia. Dogs were used throughout this series.

As noted in the first section of these reports,<sup>1</sup> nerve cell changes were found throughout the central nervous system, these changes being most marked in the cortex, less marked in the cerebellum and clearly demonstrable in the medulla and the cord. But since the Purkinje cells most graphically portray the various stages of stimulation and



exhaustion, they were used in making the differential counts, and for illustration. The differential counts given in the accompanying tables were made by Dr F W Hitchings, the description of the cell changes was made by Dr J B Austin. Appreciation is also due to Dr Hitchings for the collection of the data presented in this section of this report, in which it has seemed best to present a fairly complete description of the groups of experiments which have had the most important influence on our conclusions regarding the essential factor in the production of shock.

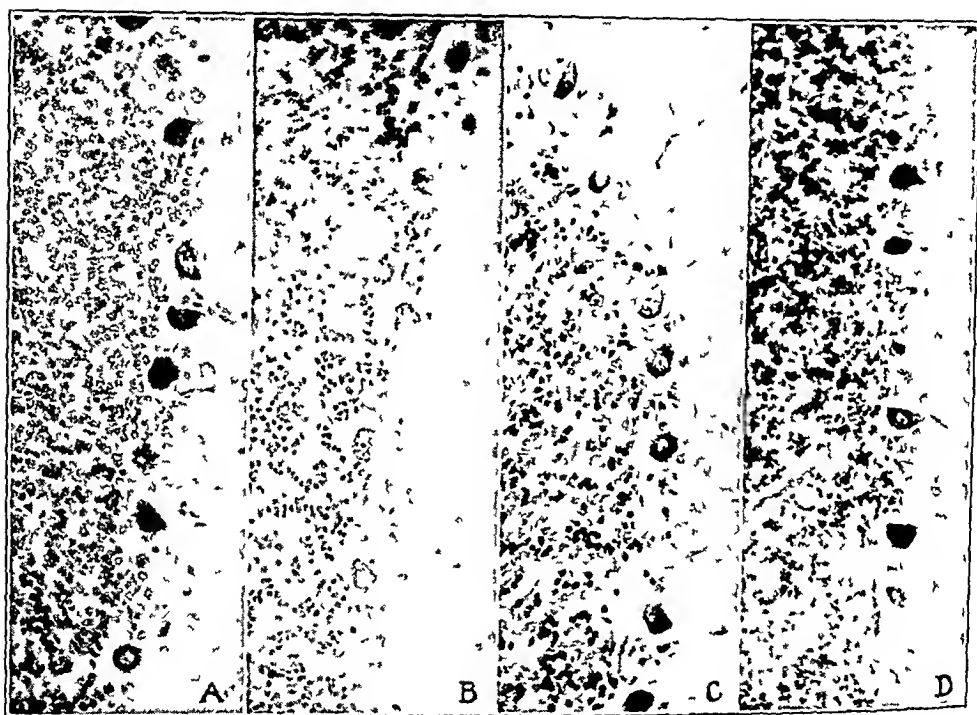


Fig 4—Effect on the brain cells of abdominal trauma. *B* under ether anesthesia, *C*, under nitrous oxide anesthesia, *D*, after severance of the spinal cord at the level of the seventh cervical vertebra. *A*, section of normal cerebellum (reduced from photomicrographs,  $\times 310$ )

## I EFFECT OF ABDOMINAL TRAUMA ON THE NERVE CELLS

### GROUP 1 ABDOMINAL TRAUMA UNDER ETHER ANESTHESIA

EXPERIMENT 1—July 1, 1909. Full ether anesthesia and morphin,  $\frac{1}{2}$  gram (0.032 gm), were used. A dog was reduced to complete surgical shock by means of physical injury without hemorrhage; the blood pressure being taken from the carotid artery in the usual way.

The blood pressure at the beginning of the experiment was 80 mm. After shock-producing manipulations for ninety minutes, the blood pressure was 14 mm. That the dog was in profound shock was evidenced by the fact that no rise in pressure followed the burning of a paw. Sections of the central nervous system were removed and the dog was killed while still under anesthesia.

**Histologic Examination—The Cerebrum** In the first examination of sections stained by Nissl's method and erythrosin, a few large hyperchromatic pyramidal cells were found. In the extranuclear part of almost all of the other cells, the chromatin was in a state of fine division. The nuclei were not always intact, and many of the nucleoli were disintegrated. These findings were confirmed in two subsequent examinations of freshly cut and stained sections. In a fourth section, the changes seemed even more marked, the large pyramidal cells having a much altered nucleoplasmic relationship. There was marked loss of chromatin, in most of the cells, it had almost disappeared. In some cells, the structure of the nucleus was altered, and the nucleolus was disintegrated. In every case, the findings with the Nissl erythrosin stain were confirmed with borax carmin-hematoxylin.

**The Cerebellum** Sections from the cerebellum were examined in detail, and a differential count of 100 Purkinje cells was made (Table 2)

PerCent	10	20	30	40	50	60	70	80
<u>Active</u>	"Spinal" Dog							
	Normal							
<u>Fatigued</u>	"Spinal" Dog							
	Normal							
<u>Exhausted</u>	"Spinal" Dog							
	Normal							

Fig 5—Effect on the brain cells of abdominal trauma immediately after the severance of the spinal cord at the level of the seventh cervical vertebra (differential Purkinje cell counts)

**The Medulla** The sections from the medulla stained well by both Nissl's method and with borax carmin-hematoxylin. Four of the nuclei of the medulla were present. In three sections, there were very few hyperchromatic cells. In one section, cells in all stages were seen, from the hyperchromatic to those in the exhausted stages.

**The Cervical Cord** No hyperchromatic cells were found. Most of the cells had large granules of chromatin, but, in some the granules were fine and less numerous. In cells from the posterior horn the nucleoplasmic relationship was disturbed.

**Comment**—This was a severely shocked animal, and the brain cell changes corresponded to those produced by physical exhaustion, insomnia, emotion, etc.

**EXPERIMENT 2**—July 2 1909. Ether anesthesia and morphin,  $\frac{1}{2}$  grain (0.032 gm) were used. The blood pressure at the beginning of the experiment was 120 mm, but it fell almost immediately to 72 mm. After shock-producing manipula-

tions for one hour, the blood pressure was 56 mm, and when a paw was burned the pressure did not rise Portions of the central nervous system were removed and immediately placed in the fixative solution The dog was killed while still under anesthesia

*Histologic Examination*—The Cerebrum An occasional large hyperchromatic pyramidal cell was seen All the large pyramidal cells showed large, vacuolated nuclei, and absence of, or very finely divided, extranuclear chromatin The nuclear membrane was always very distinct, and there did not seem to be any exhausted cells In three other subsequent examinations, the findings were practically the same, excepting that in the last one some exhausted cells with broken-down nuclei were found

The Cerebellum A differential count of the Purkinje cells was made (Table 2)

The Medulla No exhausted cells were found The chromatin was reduced in quantity and more finely divided than in normal cells Many cells showed

Per Cent	10	20	30	40	50	60	70	80
<u>Active</u>	"Spinal" Dog							
	Normal							
<u>Fatigued</u>	"Spinal" Dog							
	Normal							
<u>Exhausted</u>	"Spinal" Dog							
	Normal							

Fig 6—Effect on the brain cells of abdominal trauma, two and one-half months after severance of the spinal cord at the level of the seventh cervical vertebra (differential Purkinje cell counts)

enlarged nuclei Hyperchromatic cells were present, but were not numerous The sections contained the nuclei of the olive, the accessory olive and portions of the eighth to the twelfth cranial nerves Findings with both Nissl's stain and borax carmin-hematoxylin were consistent

The Dorsal Cord The cells of the anterior horn showed less change than those of Clarke's column In the former, there were a few hyperchromatic cells, while, in the latter, the chromatin was scanty and finely divided All the sections stained rather poorly

*Comment*—In this animal, shock was much less severe than in the animal used in Experiment 1, and we found consistently that the cell changes were less marked

EXPERIMENT 3—July 17, 1909 Ether anesthesia and morphin, ½ grain, were used At the beginning of the experiment, after the abdomen was opened, the

blood pressure was 110 mm. After shock-producing manipulations for two and one-quarter hours the blood pressure was 50 mm. The dog died a few minutes later. Portions of the central nervous system were removed immediately after death.

*Histologic Examination*—The Cerebrum. Few of the large pyramidal cells showed hyperchromatism. There were many cells in the first stage of fatigue and many exhausted cells. In some of the latter, the nucleolus was disintegrated, and the entire cell was vacuolated and edematous, or showed a ruptured cell membrane. In making a second examination from newly cut sections, it was found that the various elements were poorly differentiated. When not overstained, the chromatin seemed to be entirely gone.

The Cerebellum. Two differential counts of 100 Purkinje cells each gave the following results:

	Active Cells, per Cent	Fatigued Cells, per Cent	Exhausted Cells, per Cent
Count 1	31	34	35
Count 2	35	55	10
Normal dog count	71.2	28.1	0.7

The Dorsal Cord. Most of the cells showed absence of, or poorly stained, chromatin. There were no hyperchromatic cells, and only occasionally a cell with large and well-stained granules. All grades of exhausted cells were found, some with the nucleolus completely disintegrated.

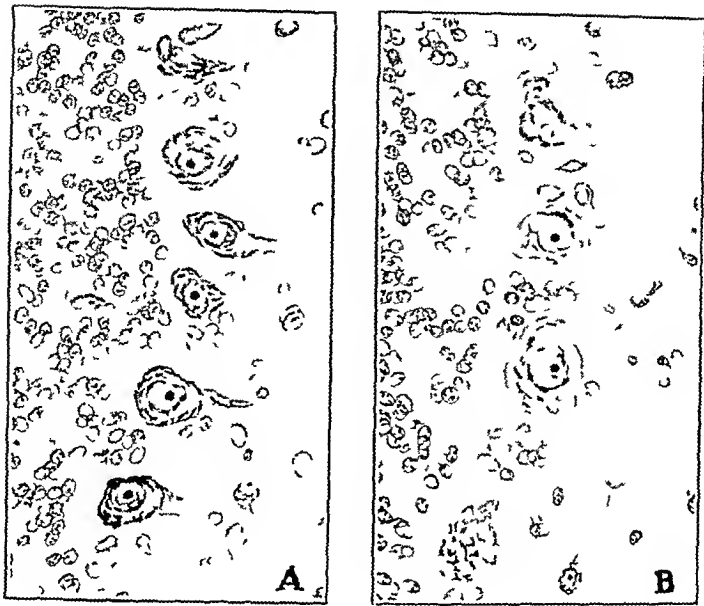
EXPERIMENT 4—Sept 19, 1909. Ether anesthesia and morphin,  $\frac{1}{4}$  grain (0.016 gm.), were used. At the beginning of the experiment, before the abdomen was opened, the blood pressure was 120 mm. After shock-producing manipulations of the intestines for three and one-half hours the blood pressure was 74 mm, and when a paw was burned, the blood pressure rose and the dog showed no symptoms of shock. It was killed after sections of the nervous system had been removed.

*Histologic Examination*—The Cerebrum. Only a few hyperchromatic large pyramidal cells were found. The chromatin was in an extremely fine state of division in a large majority of the cells. The nuclei were intact and the nucleoli well stained. Some cells showed a few large chromatin granules, and there were also several exhausted cells. A second examination of new sections only revealed a few hyperchromatic cells. The enlargement of the nuclei was extremely marked, the nucleoplasmic relationship being normal in only a few cells. In some cases, the nucleolus had broken down altogether, while in others it was poorly stained. A third examination revealed the same changes.

The Cerebellum. The differential count of 100 Purkinje cells is given in Table 2.

The Medulla. The larger cells were affected less than the smaller. The nuclei of the cranial nerves and the cells of the reticular formation were almost all hyperchromatic, or, at least, were filled with large granules of chromatin. In the olivary nucleus, there were hardly any hyperchromatic cells. The number of granules was greatly diminished, but still most of the cells had a few scattered granules of good size. No exhausted cells were found, the nucleus in all cases being intact. A second examination confirmed these findings.

The Dorsal Cord. Almost all of the cells were hyperchromatic, the chromatin being in large granules. No fatigued or exhausted cells were found. A second examination confirmed these findings, the granules being large in all but one or two cells.



A

B

PerCent	10	20	30	40	50	60	70	80	90
Active	Shocked Dog								
	Unshocked Dog								
	Normal								
Fatigued	Shocked Dog								
	Unshocked Dog								
	Normal								
Exhausted	Shocked Dog								
	Unshocked Dog								
	Normal								

C

Fig 7—The comparative effects of abdominal trauma on the brain cells of animals in which the main blood vessels supplying the brains were crossed by anastomosis A, section of cerebellum of untraumatized dog, B, section of cerebellum of traumatized dog, C, differential Purkinje cell counts (A and B from camera lucida drawings)

EXPERIMENT 5—Sept 30 1909 Ether anesthesia and morphin,  $\frac{1}{4}$  grain (0.008 gm), were used. Before the abdomen was opened the blood pressure was 124 mm, falling to 100 mm when the manipulations of the intestines were begun. At the end of two hours, the blood pressure was 62 mm, and rose when a paw was burned. The dog was killed, and portions of the central nervous system were removed at once.

*Histologic Examination*—The Cerebrum. No hyperchromatic cells were seen, the degree of cell alteration being very marked. Almost all the cells had lost all but a few of their chromatin granules. Many cells were in the last stages of exhaustion, with absence of chromatin, ruptured nucleus, disturbed nucleoplasmar relation and disintegrated nucleolus. At a subsequent examination of a new series of sections these findings were confirmed, except for the presence of a few hyperchromatic cells, with an assortment of small to large granules in each.

The Cerebellum. Two differential counts of 100 Purkinje cells each were made, which revealed

	Active Cells per Cent	Fatigued Cells per Cent	Exhausted Cells, per Cent
Count 1	51	41	8
Count 2	62	31	7
Normal dog count	71.2	28.1	0.7

The Medulla. The cells were markedly affected, only a few hyperchromatic cells being seen. Some large cells had large chromatin granules, but most had few granules and showed a disturbed nucleoplasmar relationship, while in all of the sections the small cells showed evidence of fatigue. Some hyperchromatic cells were found, but, in almost all, a great loss and thinness of division of the granules were shown. The cells of the reticular formation were all hyperchromatic.

The Cord. The cells of the anterior horn were mostly hyperchromatic, and contained large granules. In a few cells the granules were not as numerous but were still larger in size. The small cells were more altered, the granules being fine and the nucleoplasmar relationship disturbed. These findings were confirmed in a second examination.

The Spinal Ganglions. No hyperchromatic cells were seen. In almost all of the cells, the granules were very fine, but the nucleus was intact, and the nucleolus well stained. In each field, from one to four cells were entirely devoid of chromatin. These findings also were confirmed by a subsequent examination.

## GROUP 2 ABDOMINAL TRAUMA UNDER NITROUS OXID-OXYGEN ANESTHESIA

EXPERIMENT 6—May 19, 1909 Nitrous oxid-oxygen anesthesia and morphin were used. At the beginning of the experiment, the blood pressure was 120 mm, after manipulations for two hours, it had fallen only to 110 mm, and when a paw was burned it immediately rose to 120 mm. There was no clinical evidence of shock at any time. The dog was killed with chloroform, and portions of the central nervous system removed immediately.

*Histologic Examination*—The Cerebrum. Most of the cells showed a greatly disturbed nucleoplasmar relationship. There were also many hyperchromatic cells with large granules. Apparently, there were no exhausted cells. A second careful search with high magnification also failed to reveal any exhausted cells.

The Cerebellum. The results of a differential count of 100 Purkinje cells are given in Table 4.

**The Cervical Cord** The large motor cells of the anterior horns showed no changes. There were no hyperchromatic cells apparent, but all the cells had large chromatin granules which extended into the dendrites. The cells of the posterior horns showed disturbance of the nucleoplasmic relationship, with diminished chromatin, and in some cases entire absence of chromatin. The nuclei were vacuolated. This condition was in marked contrast to that of the large motor cells, and could not possibly have been due to either fixation or staining.

**EXPERIMENT 7—July 9, 1909** Under nitrous oxide-oxygen anesthesia and morphin, the usual shock-producing manipulations of the intestines were made for two and one-half hours, during which time the blood pressure fell from about 120 mm to 56 mm. As the blood pressure fell to 60 mm when the

TABLE 2—THE EFFECTS OF ABDOMINAL TRAUMA ON THE PURKINJE CELLS OF DOGS UNDER THE INFLUENCE OF ETHER-MORPHIN ANESTHESIA

	Group 1	Differential Counts		
		Active Cells, per Cent	Fatigued Cells, per Cent	Exhausted Cells, per Cent
Experiment 1		31	42	27
Experiment 2		50	45	5
Experiment 3		33	44.5	22.5
Experiment 4		58	32	10
Experiment 5		56.5	36	7.5
Averages		45.7	39.9	14.4
Normal average		71.2	28.1	0.7

TABLE 3—COMPARISON OF THE PURKINJE CELL COUNTS IN NORMAL AND IN TRAUMATIZED DOGS\*

	Differential Counts		
	Active Cells, per Cent	Fatigued Cells, per Cent	Exhausted Cells, per Cent
Experiment 1			
Normal dog	73	27	0
Traumatized dog	42	52	6
Experiment 2			
Normal dog	71	28	1
Traumatized dog	30	55	15

\* In each of these experiments, a section from the cerebellum of a normal dog and one from the cerebellum of a traumatized dog were mounted on the same slide and stained and counted by identical technique.

abdomen was opened, it was evident that but a small part of the total fall was due to the subsequent manipulation. At the end of the experiment, there were moderate clinical signs of shock. Portions of the central nervous system were removed *intra vitam*, and the dog was killed while under anesthesia.

**Histologic Examination—The Cerebrum** The findings in a series of sections with several different fixations and stains were constant. In each were many hyperchromatic cells, chiefly among the large pyramidal cells. The smaller cells showed an almost total loss of extranuclear chromatin, except, usually, a few scattered granules around the periphery. The nuclei were large and unbroken. The nucleoli were usually well stained. There were no exhausted cells. In these cells, there was some disturbance of the nucleoplasmic relation.

**The Cerebellum** The results of a differential count of 100 Purkinje cells are given in Table 4

**The Medulla** Most of the cells were small and showed marked fatigue but not exhaustion. They contained very few granules of chromatin, the nuclei were large and vacuolated, and the nucleoli usually well stained. A second series of sections was cut through the nucleus cuneatus and nucleus gracilis. The cells of the remainder of the anterior horn showed the following changes. The motor nuclei around the fourth ventricle showed hyperchromatic cells, and cells with many and larger granules than the foregoing.

**The Cord** The block from the spinal cord was cut incorrectly, so that, when the sections were cut from it, only the anterior horn cells showed. These were well stained, had large granules and showed a tendency to hyperchromatism.

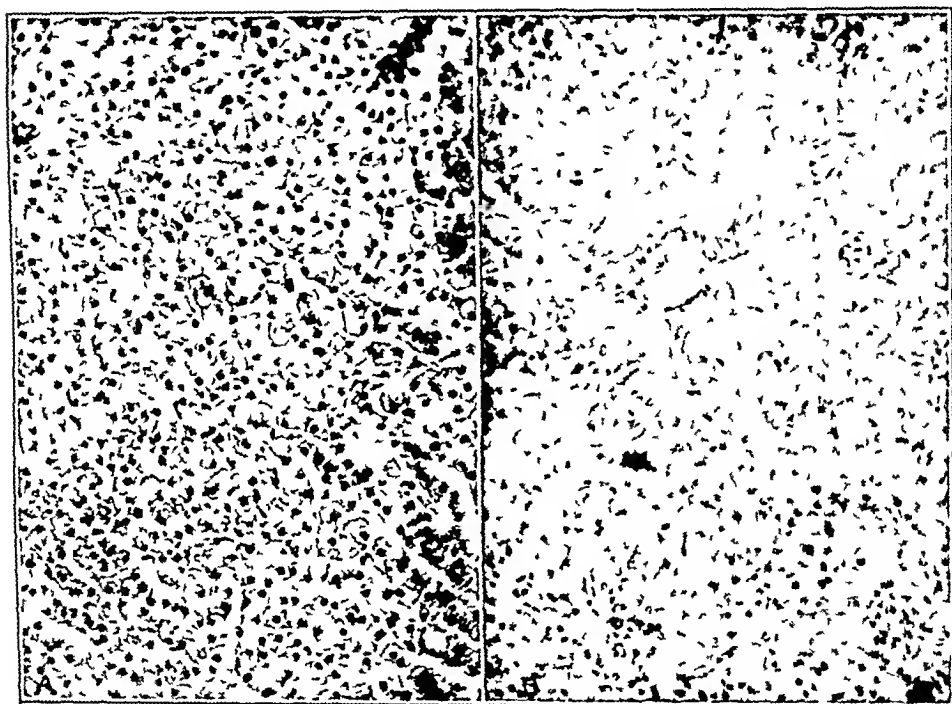


Fig 8—Effect of physical trauma on the liver. *A*, section of liver of a normal dog; *B*, section of liver of a dog which had been subjected to severe abdominal trauma (reduced from photomicrographs,  $\times 310$ )

**EXPERIMENT 8—June 10, 1909** Under nitrous oxid-oxygen anesthesia and morphin, during two hours of intestinal manipulation, the blood pressure fell from 110 mm to 90 mm. Although the manipulation was severe, no marked symptoms of shock were present at the close of the experiment. Portions of the central nervous system were removed *intra vitam*, and the animal was killed while under anesthesia.

**Histologic Examination**—**The Cerebrum** Many of the large pyramidal cells showed changes but no disintegration of the nucleoli. There were many hyperchromatic cells, but most of the cells were in the first stage of fatigue. These findings were confirmed by the examination of a second set of sections.

**The Cerebellum** The results of a differential count of 100 Purkinje cells are given in Table 4.



**The Medulla** The cells were beautifully stained. Many were hyperchromatic, and all of the rest had large, distinct chromatin granules. The cells of the column of Burdach and those around the points of origin of the cranial nerves, as well as around the fourth ventricle, showed no evidence of fatigue.

**The Pons** Most of the cells of the pontine nuclei were hyperchromatic, and none showed loss of chromatin or fatigue changes.

**The Cord** The large cells of the anterior horn of the cervical cord showed, in many cases, a loss of chromatin from the dendrites, and a few showed finer granules than those in normal cells and slight evidences of fatigue. In the upper dorsal cord, many cells of the anterior horns had large granules, and many were hyperchromatic. In the smaller and commissural cells, there were smaller and fewer granules. The nucleoplasmic relationship in these cells was altered, the nuclei being very large. The nucleolus was always well stained, and intact.

**EXPERIMENT 9**—June 18, 1909. Nitrous oxide-oxygen anesthesia and morphin were used. After the abdomen was opened, the blood pressure was 130 mm. The intestines were manipulated for two hours without hemorrhage, the blood pressure falling to 66 mm. The heart action was strong at this time, and only moderate shock was present. When a paw was burned, the blood pressure rose to 170 mm. The animal was killed while under anesthesia, and portions of the central nervous system were removed immediately after death.

**Histologic Examination**—The Cerebrum. In most of the large pyramidal cells, the granules were fine, but, in some, they were absent. The nuclei were intact, and the nucleoli were well stained. The smaller cells (and some of the larger ones) had very large nuclei. A few hyperchromatic cells were found, but some cells were fatigued almost to the point of exhaustion.

**The Cerebellum** The results of a differential count of 100 Purkinje cells are given in Table 4.

**The Medulla** There were a few hyperchromatic cells, and almost all showed the presence of large granules of chromatin, although in some cells, the granules were few in number and an occasional exhausted cell was found. The level at which all the sections were taken was not determined. In one series of sections from the low medulla, a large number of cells near the point of exit of a motor nerve were in good condition, their granules being large but not numerous. Scattered throughout the fields were many large cells which showed disturbance of the nucleoplasmic relationship and almost complete absence of granules. In some places, the cells were completely exhausted and entirely broken down. There were no hyperchromatic cells.

**The Lumbar Cord** The sections were taken at the lumbar enlargement. Almost all the cells contained large and numerous granules of chromatin, and did not seem to be at all fatigued. There were no hyperchromatic cells.

**EXPERIMENT 10**—July 5, 1909. Nitrous oxide-oxygen anesthesia and morphin,  $\frac{1}{2}$  grain (0.032 gm.), were used. At the beginning of the experiment, the blood pressure was 100 mm., and it did not fall when the abdomen was opened. At the end of three hours of shock-producing manipulation, the blood pressure had fallen to 76 mm. but showed reaction to 84 mm. when a paw was burned. Slight symptoms of shock were present. Portions of the central nervous system were removed intra vitam and the animal was killed while under anesthesia.

**Histologic Examination**—The Cerebrum. Some of the large pyramidal cells were hyperchromatic. Most of the cells were in fair condition, with large masses

of extranuclear chromatin. There was some nuclear vacuolization, but it was not very marked.

**The Cerebellum** A differential count of 100 Purkinje cells is given in Table 4.

**The Medulla** The sections were taken from a low level. There were marked changes in the cells of the nucleus cuneatus and nucleus gracilis. In most of the cells, there was little chromatin present, and almost all showed disturbance of the nucleoplasmic relation. The cells of the anterior horn were in fairly good condition, many being hyperchromatic.

**The Upper Cervical and Dorsal Cord** In most of the cells the granules were large but scattered, and withdrawn from the dendrites in all except a

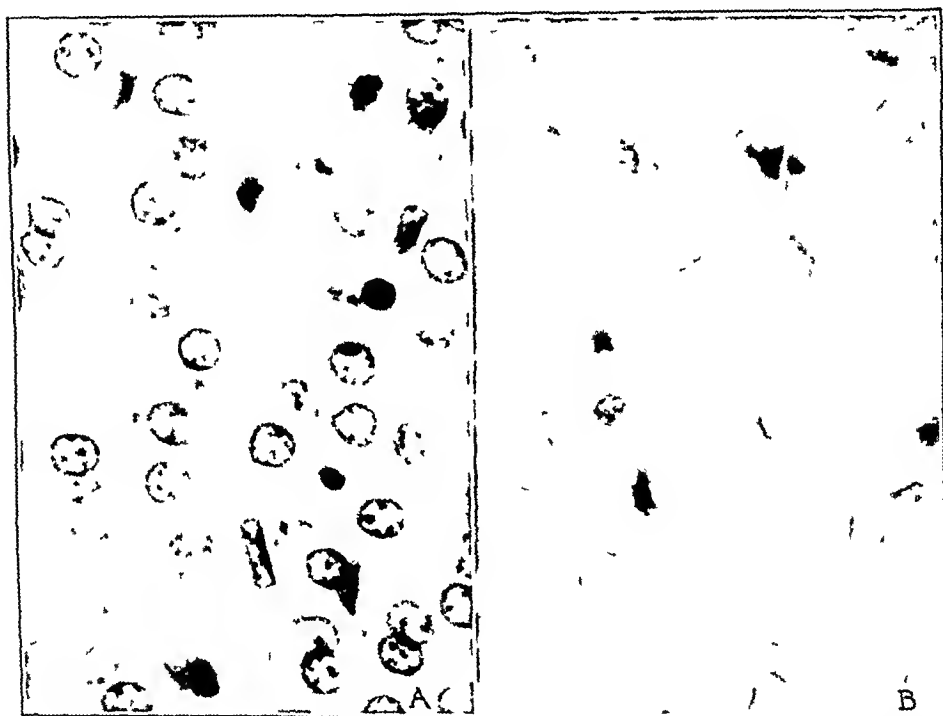


Fig 9—Effect of physical trauma on the liver. *A*, section of liver of a normal dog, *B*, section of liver of a dog which had been subjected to severe abdominal trauma (reduced from photomicrographs,  $\times 1,640$ )

few instances. Most of the cells seemed to be approaching the first stage of fatigue, but there was no disturbance of the nucleoplasmic relation.

**EXPERIMENT 11**—June 11, 1909 Nitrous oxide-oxygen anesthesia and morphin were used. After opening the abdomen, the blood pressure was 130 mm. Although the intestines were manipulated for three hours, no symptoms of profound shock appeared, and the blood pressure fell to only 96 mm, rising to 108 mm when a paw was burned. Portions of the central nervous system, with the exception, through accident, of the cerebellum, were removed *intra vitam*. The animal was killed while under anesthesia.

**Histologic Examination**—**The Cerebrum** Many hyperchromatic cells were present, although a majority showed a diminished chromatin content outside the nucleus. The granules were fine. The nuclei were vacuolated, but the

nucleoli were always intact and well stained. On restaining, some cells were found, in each of which the nucleus had a ruptured membrane, and had broken down. Because of these different results, three other examinations were made in which, for the most part, the changes found were those first described.

**The Cervical Cord.** There were many hyperchromatic cells and others with finely divided or diminished chromatin.

**The Dorsal Cord.** The same conditions were found, with the granules much less abundant than in normal cells.



Fig 10—Effect of physical trauma on the suprarenals. *A*, section of suprarenal of a normal dog, *B*, section of suprarenal of a dog which had been subject to severe abdominal trauma (reduced from photomicrographs,  $\times 310$ )

**The Spinal Ganglions.** The cells of the spinal ganglions attached to the sections from the cord showed variation in the size of the granules, most of which were finely divided. The nuclei were normal.

**EXPERIMENT 12—**June 3, 1909. Nitrous oxid-oxygen anesthesia and morphin,  $\frac{1}{2}$  gram, were used. Before opening the abdomen the blood pressure was 130 mm. After manipulating the intestines for two hours, the general condition of the dog was good, there were no signs of shock, and the blood pressure had fallen to only 110 mm. Portions of the central nervous system were removed *intra vitam*, and the dog was killed while under anesthesia.

**Histologic Examination—The Cerebrum.** Many of the large pyramidal cells were hyperchromatic. No exhausted cells were found. Most of the cells showed well stained chromatin. The nuclear membrane was unbroken, but usually shrunken. The nucleolus was always well stained. On staining new sections

from the same block, less marked changes than the foregoing were found, there being fewer hyperchromatic cells, with numerous large granules in most of the cells, there were no exhausted cells and no nuclear shrinkage. The findings were the same with Nissl's stain, and with borax carmalum-hematoxylin.

The Medulla. Sections were taken at the sensory decussation. The cells of the anterior horn were well stained, the granules being large and numerous. The nucleus cuneatus and nucleus gracilis contained cells which were markedly fatigued, even to the point of exhaustion. The nuclei were vacuolated, as in some cases was the cytoplasm also. The smaller commissural cells also had undergone

TABLE 4—THE EFFECTS OF ABDOMINAL TRAUMA ON THE PURKINJE CELLS OF DOGS UNDER THE INFLUENCE OF NITROUS OXIDE-OXYGEN-MORPHINE ANESTHESIA

	Differential Counts		
	Active Cells, per Cent	Fatigued Cells, per Cent	Exhausted Cells, per Cent
Group 2			
Experiment 6	83	17	0
Experiment 7	61	33	6
Experiment 8	84	12	4
Experiment 9	57	39	4
Experiment 10	54	41	5
Averages	67.8	28.4	3.6
Normal average	71.2	28.1	0.7

TABLE 5—EFFECT OF PHYSICAL TRAUMA ON THE PURKINJE CELLS

	Differential Counts		
	Active Cells, per Cent	Fatigued Cells, per Cent	Exhausted Cells, per Cent
Trauma under ether	45.7	39.9	14.4
Trauma under nitrous oxide	67.8	28.4	3.8
Normal	71.2	28.1	0.7
Ether anesthesia—four hours*	68.1	27.9	4.0
Nitrous oxide anesthesia—four hours*	77.0	22.0	1.0

\* In order to form a basis for judgment as to what degree the effect of trauma on the brain cells is due to the anesthetic, these figures are appended.

changes resulting in loss of chromatin in the granules and in disturbance of the nucleoplasmic relationship.

The Upper Cervical and Dorsal Cord. Sections from both levels contained cells in good condition. In most instances, the chromatin was well distributed, but showed a tendency to recede from the dendrites. There was also a tendency toward hyperchromatism.

#### GROUP 3 ABDOMINAL TRAUMA AFTER COMPLETE CROSS SECTION OF THE SPINAL CORD

The object of these experiments was to determine whether shock-producing afferent impulses from the abdomen could reach and injure the brains of dogs after complete cross-section of the spinal cord between the sixth and seventh cervical vertebrae.

EXPERIMENT 1—*Abdominal trauma two and one-half months after complete cross-section of the spinal cord* Sept 17, 1910. Two and one-half months

before this date, under ether anesthesia, the spinal cord of a dog in good condition was severed between the sixth and seventh cervical vertebrae. The convalescence was stormy, but recovery finally took place, with the exception of complete paralysis below the level at which the section was made, there being a late return of the scratch reflex only. September 17, the dog was anesthetized again with ether and morphin,  $\frac{1}{2}$  gram, and subjected to intestinal manipulations. When the experiment started, burning both a front and hind paw did not cause any appreciable rise in blood pressure, although in a normal dog this would have caused a rise of from 10 to 20 mm at least. After four hours of constant intestinal manipulation the blood pressure had fallen only 8 mm, and burning the paws caused no more reaction than before. At this time, portions of the central nervous system were removed *intra vitam*, and the dog was killed while under anesthesia.

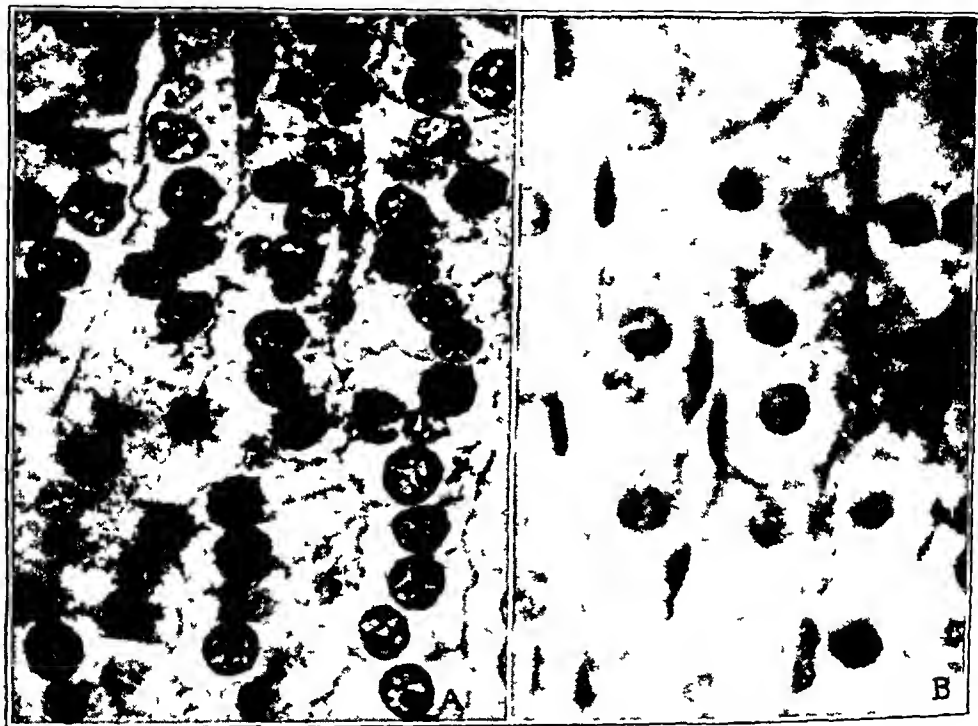


Fig 11—Effect of physical trauma on the suprarenals. *A*, section of suprarenal of a normal dog, *B*, section of suprarenal of a dog which had been subjected to severe abdominal trauma (reduced from photomicrographs,  $\times 1640$ )

*Histologic Examination*—*The Cerebrum* The sections were well stained, the cells containing many granules with a normal amount of chromatin. No exhausted cells were found.

*The Cerebellum* A differential count of 100 Purkinje cells is given in Table 6.

*The Spinal Cord* Above the cross-section, the cells were in normal condition in both the anterior and posterior horns, the granules being large and well stained. At the point of division, the normal tissue had been entirely replaced by connective tissue in bundles.

Below the cross-section, the central canal of the cord was greatly enlarged. The motor cells of the anterior horn were still present. Some were normal in

size and well stained. Others contained finely divided chromatin granules, while an occasional cell was in an exhausted condition. The greatest changes were in the posterior horns. All the cells of Clarke's column and those around the posterior horns showed total loss of chromatin.

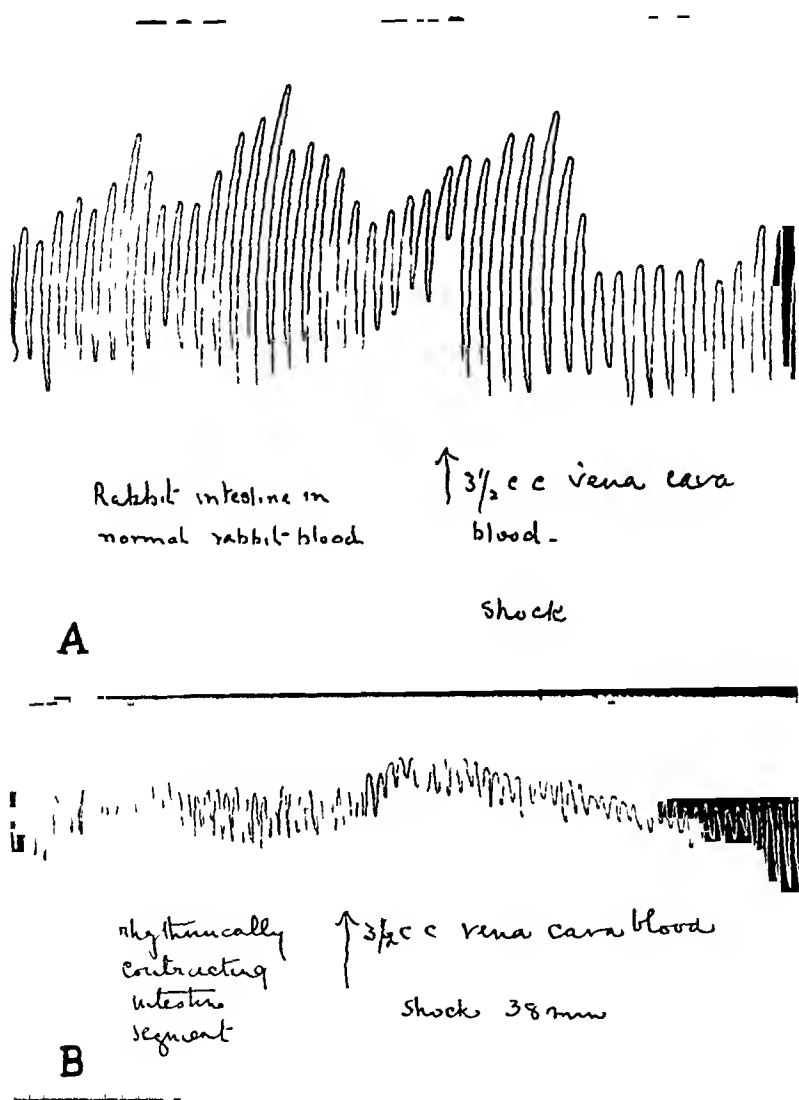


Fig 12—Cannon test for epinephrin after abdominal trauma. The lack of reaction when blood from traumatized dogs was substituted for normal blood may be noted. Duration of trauma: Dog A, fifteen minutes; Dog B, thirty-eight minutes.

EXPERIMENT 2—*Abdominal trauma immediately after complete cross-section of the spinal cord.* Dec 6, 1911. Ether anesthesia only was used. The spinal cord was severed at the seventh cervical vertebra. There was immediately such a marked fall in blood pressure that it was necessary to transfuse blood from another dog. The abdomen was then opened, and severe shock-producing

manipulations were begun in the usual way. It was found to be impossible to maintain the blood pressure, since blood began to ooze from the liver as soon as the pressure rose. The transfusion was, therefore, made intermittent, only a small amount of blood being allowed to pass at a time. The blood pressure never fell below 30 mm. The animal was killed by stabbing after being subjected to the intestinal manipulations for three hours. The pulse and respiratory rates remained the same throughout the experiment. At necropsy, the complete cross-section of the spinal cord was verified.

*Histologic Examination*—The Cerebrum. There was a great preponderance of hyperchromatic cells. In many cells, the granules were not very distinct, the chromatin being somewhat diffused. Very few cells showed any loss of chromatin.

The Cerebellum. A differential count of 100 Purkinje cells is given in Table 6.

EXPERIMENT 3—*Abdominal trauma immediately after complete cross-section of the spinal cord*. Dec 7, 1911. Ether anesthesia only was used. The experimental details were the same as in the preceding experiment. One and one-half hours after intestinal manipulations had been begun, the heart suddenly stopped beating as a result of excess of ether. The dog was resuscitated, but it was necessary to administer cardiac massage almost constantly. It was thought that this accident might invalidate the results, but the following data show that it did not. Death occurred at the end of another half hour, or after two hours of manipulations of the intestines.

*Histologic Examination*—The Cerebrum. There were many hyperchromatic cells and very few which showed loss of chromatin. The general appearance was normal.

The Cerebellum. A differential count of 100 Purkinje cells is given in Table 6.

EXPERIMENT 4—*Abdominal trauma immediately after complete cross-section of the spinal cord*. Dec 14, 1911. Ether anesthesia only was used. The details were the same as in the two preceding experiments. This dog also had to be resuscitated at about the middle of the experiment. The manipulations were continued for three hours, the pulse and respiratory rates being unchanged during that time. As the blood pressure fell, blood was transfused from another dog.

*Histologic Examination*—The Cerebellum. A differential count of 100 Purkinje cells is given in Table 6.

#### COMMENT

This group of experiments indicates that in an animal whose spinal cord has been completely severed no amount of trauma of the distal territories of the body will cause either subjective symptoms of shock or physical changes in the brain cells (Table 6).

#### GROUP 4 TRANSFUSION OF BLOOD FROM A DOG IN SHOCK TO A NORMAL DOG

In the following experiments the object was to determine whether shock could be transmitted through the blood from a shocked to an unshocked dog. In the first experiments, a dog was subjected to profound shock, and his blood was then transfused to a sound dog.

In two other experiments (the so-called "sympathetic shock" experiments), in each instance, a carotid artery of one dog was anastomosed to a carotid artery of another dog, and an internal jugular vein of one to an internal jugular of the other, the normal directions of current flow being preserved. The blood pressure was taken from the remaining carotid artery of each dog and recorded in the usual way. Ether-morphin anesthesia was used, and each animal was killed before regaining consciousness.

TABLE 6—EFFECT ON THE PURKINJE CELLS OF TRAUMA AFTER COMPLETE CROSS-SECTION OF THE SPINAL CORD

	Group 3	Differential Counts		
		Active Cells, per Cent	Fatigued Cells, per Cent	Exhausted Cells, per Cent
Experiment 1		80	19	1
Experiment 2		80	19	1
Experiment 3		79	21	0
Experiment 4		89	11	0
Average		82	17.5	0.3
Normal average		71.2	28.1	0.7

TABLE 7—COMPARATIVE EFFECTS ON THE PURKINJE CELLS OF THE TRAUMATIZED AND OF THE UNTRAUMATIZED DOGS IN CROSSED CIRCULATION EXPERIMENTS

	Differential Counts					
	Traumatized Dogs			Untraumatized Dogs		
	Active Cells, per Cent	Fatigued Cells, per Cent	Exhausted Cells, per Cent	Active Cells, per Cent	Fatigued Cells, per Cent	Exhausted Cells, per Cent
Experiment 1				80	20	0
Experiment 2	42	52	6	73	27	0
Experiment 3	30	55	15	71	28	1
Average	36	53.5	10.5	74.6	25	0.3
Normal average	71.2	28.1	0.7			

By this sympathetic arrangement, physiologic continuity of circulation was established, and could be maintained indefinitely. Consequently when one dog of each pair was subjected, for at least three hours, to severe shock-producing manipulations of the intestines it would be expected that if toxic products were formed and liberated into the blood stream, or if shock were due to some alteration in the gaseous content of the blood, they would be transmitted to and affect the brain of the other dog. It would also be expected that it would take a longer time to reduce the manipulated dog to shock, since his blood pressure was maintained, to a certain extent, by the support of the circulation from the normal dog.



The Purkinje cell counts in these three experiments are given in Table 7

#### COMMENT

From these experiments, it is apparent that no toxic substances are found in the blood during shock, certainly none of sufficient virulence to have any destructive effect on the brain cells. The tendency toward hyperchromatism is readily explained by the duration of the experiments and the effects of the ether. The important fact is that a negligible percentage of exhausted cells was found and that the clinical symptoms of shock did not appear in the untraumatized dogs.

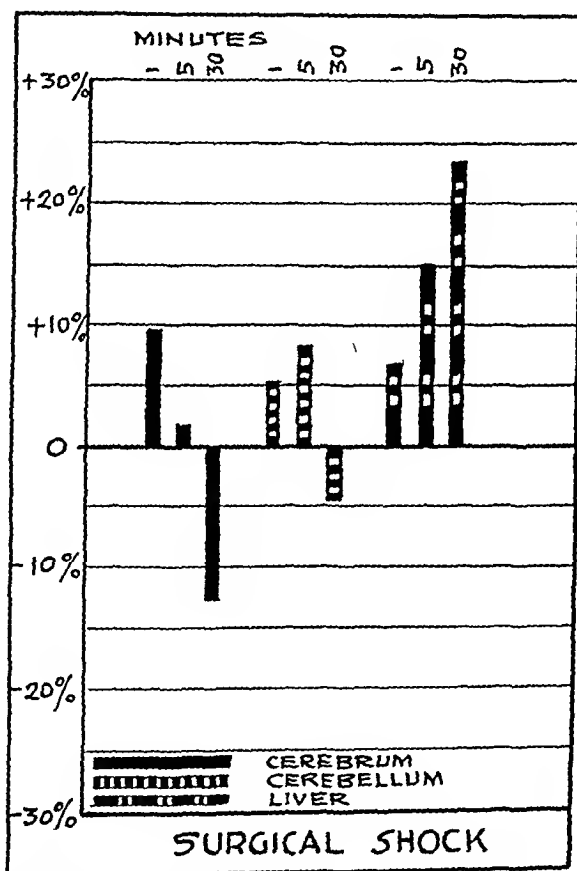


Fig 13—Early and late effects of abdominal trauma on the electric conductivity of the brain and the liver

#### GROUP 5 MISCELLANEOUS EXPERIMENTS

Under this heading are described five experiments in which there were, accidentally or intentionally, factors which caused variations from the typical experiments described in Groups 1 and 2

**EXPERIMENT 1**—*The effects of abdominal trauma on a dog under interrupted nitrous oxid-oxygen anesthesia and morphin*. The purpose of this experiment was to determine the effect on the brain cells of a bad technic in administering the anesthetic

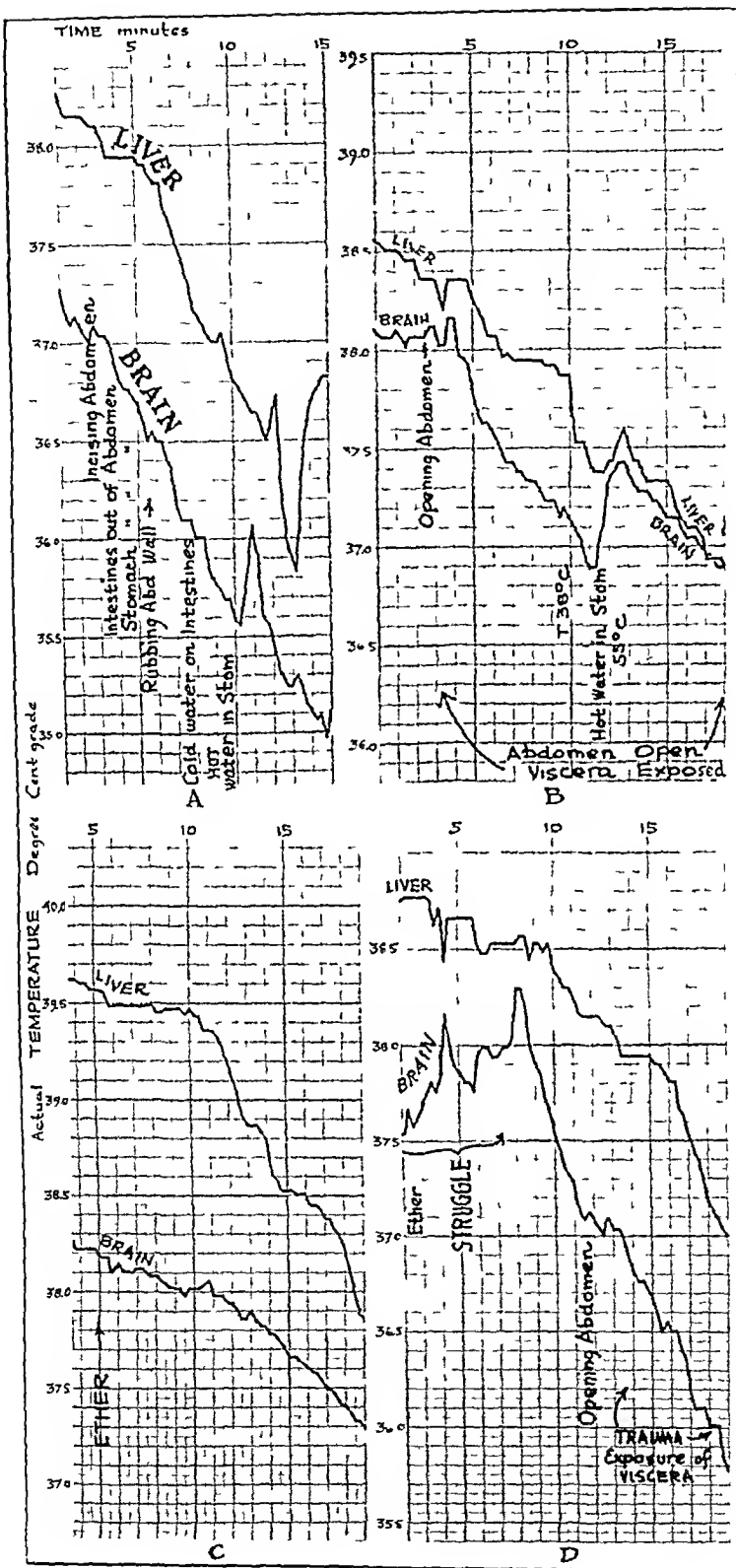


Fig 14—Temperature variations in the brain and the liver produced by abdominal trauma (thermocouple measurements) In each of these experiments under ether anesthesia, the abdomen was opened and the intestines and abdominal wall were subjected to shock-producing manipulations In C, the manipulations were more moderate than in the other experiments

June 8, 1909 Under interrupted nitrous oxide-oxygen anesthesia and morphin, the intestines were manipulated constantly for two hours, during which period the blood pressure fell from 110 mm to 40 mm, the principal fall occurring when the anesthetic was interrupted. At the end of the experiment, a rise of 10 mm occurred when a paw was burned. Portions of the central nervous system were removed, and the dog was killed while under anesthesia.

*Histologic Examination*—The Cerebrum There were scarcely any hyperchromatic cells. Most of the cells showed a marked loss of granules, such granules as remained being in a finely divided state. Most of the nuclei were vacuolated, and the nuclei were well stained. The smaller pyramidal cells did not have as large a nucleus as is usual. No markedly exhausted cells were found.

The Cerebellum A differential count of 100 Purkinje cells was as follows:

	Active Cells, per Cent	Fatigued Cells, per Cent	Exhausted Cells, per Cent
Count 1	62	34	4
Normal dog count	71.2	28.1	0.7

The Medulla Most of the motor cells around the fourth ventricle and most of the commissural cells were hyperchromatic. The greatest changes were found in the accessory olive, and those next in degree, in the olive itself. The cells were fatigued but not exhausted, that is, the chromatin granules were diminished in number and size, and the nuclei were enlarged. The cells of the anterior horns were not so hyperchromatic as were the cells of the motor nerves.

The Cord In the cervical cord, both in the anterior horns and in the commissure, most of the cells contained numerous large separate granules. Many of the cells were hyperchromatic.

EXPERIMENT 2—*The effects of abdominal trauma under ether-morphin anesthesia on a dog that had distemper and that had fasted five days.* Sept. 29, 1909. Ether anesthesia and morphin,  $\frac{1}{8}$  grain, were used. The animal had fasted for five days, and had drunk very little water during this time. It coughed and had a discharge from its nose. Before the abdomen was opened, the blood pressure was 110 mm, falling to 78 mm when the abdomen was opened. The animal was soon in profound shock, and, at the end of one and one-half hours of intestinal manipulation, the pressure had fallen to 34 mm when the animal almost expired. When a paw was burned, the pressure did not rise. Portions of the central nervous system were removed before death occurred.

*Histologic Examination*—The Cerebrum As a whole, the changes in the nerve cells were very marked. There were no hyperchromatic cells, and only an occasional granule of chromatin was seen in any of the cells, in many of which the nuclear membrane was torn and the nucleolus disintegrated. Sections from another block of cerebral tissue presented the same appearance. Restaining with borax-carmin and iron-hematoxylin gave the same results as the Nissl stain.

The Cerebellum Two differential counts of 100 Purkinje cells each were as follows:

	Active Cells, per Cent	Fatigued Cells, per Cent	Exhausted Cells, per Cent
Count 1	52	35	13
Count 2	55	35	10
Normal dog count	71.2	28.1	0.7

These two counts were made from sections taken from two different blocks of cerebellum. The slight variation between them may be noted.

The Medulla The sections did not pass through the nucleus cuneatus or the nucleus gracilis. The cells of the nuclei around the fourth ventricle

were affected. There were some hyperchromatic cells, and others in which the number of large granules was greatly reduced. The smaller cells showed greater changes, some being entirely without granules. In many cells, both large and small, the nucleus seemed to be enlarged. Sections from another part of the block passed through the nucleus cuneatus and the nucleus gracilis. For the most part, the cells in these nuclei were affected more than were those elsewhere in the section. Very few chromatin granules were present. The nuclei were intact, and the nuclei had stained well. The cells of the formatio reticularis and those around the floor of the fourth ventricle (eleventh or twelfth cranial nerve roots) had larger and more dense granules, and seemed to have been little affected. On restaining with iron-hematoxylin the same changes were found.

**The Cord.** Moderate changes were found. There were many hyperchromatic cells with large chromatin granules. A few cells had very fine granules, and their dendrites and certain areas in the protoplasm of the cell body were free from chromatin. The nuclear structures were unchanged.

**The Spinal Ganglions.** There were no hyperchromatic cells or cells with large granules, and, when chromatin was present, it was finely divided. Some cells showed great loss of chromatin. Eccentric nuclei and badly stained nucleoli were present. On staining fresh sections with Nissl's stain, the findings were the same. On restaining with borax carmin and hematoxylin, no hyperchromatic cells were found. The granules were fine for the most part, and some cells had no granules, although in a few the granules were large.

*Comment*—The high percentage of exhausted cells is readily accounted for by the fact that, in this experiment, further exhaustion from injury was added to exhaustion from disease and fasting.

**EXPERIMENT 3**—*The effects of abdominal trauma on a dog under nitrous oxid-oxygen anesthesia and scopolamin (hyoscine)*. The object of this and the following experiment was to determine whether more or less shock would be produced if scopolamin was used instead of morphin.

June 28, 1909. Nitrous oxid anesthesia and scopolamin were used. As soon as the technic for recording the blood pressure was completed, a hypodermic injection of scopolamin,  $\frac{1}{10}$  grain, was given. Twenty minutes later, the respiration and circulation ceased, but resuscitation was easily accomplished by means of cardiac massage. The abdomen was then opened, and the intestines were manipulated for one and one-half hours, during which period the blood pressure, which was 130 mm. at the beginning of the experiment, fell to 70 mm. Moderate symptoms of shock were present. There was no evidence of marked fatigue or of exhaustion.

**Histologic Examination**—**The Cerebrum.** The largest of the pyramidal cells showed little change in the number and size of the chromatin granules and had apparently been little affected. In some cells, however, the chromatin had disappeared entirely, and the nucleus was vacuolated, while the nucleolus was well stained. In others, small masses of chromatin remained within the nuclear membrane, which in some instances was ruptured. Sections from two other blocks of tissue showed the same changes. The hyperchromatic cells seemed to have more and larger chromatin granules than those in cases in which morphin was used.

**The Cerebellum.** A differential count of 100 Purkinje cells was as follows:

	Active Cells, per Cent	Fatigued Cells, per Cent	Exhausted Cells, per Cent
Count 1	79	18	3
Normal dog count	71.2	28.1	0.7

The Medulla Hyperchromatic cells were rare. Almost all of the cells had large, sharply stained granules, but, in a few, the granules were fine or had disappeared altogether from certain areas in the cytoplasm. In some cells, there was a tendency toward peripheral distribution of the granules.

EXPERIMENT 4—*The effects of shock on a dog under nitrous oxid-oxygen anesthesia and scopolamin*. June 30, 1909. Nitrous oxid-oxygen anesthesia and scopolamin,  $\frac{1}{40}$  grain, were used. Before opening the abdomen, the blood pressure was 160 mm—abnormally high, and it did not fall when the abdomen was opened. At the end of two hours of manipulations, the blood pressure had fallen to 60 mm, and mild symptoms of shock were present. The heart action showed very little irregularity. Portions of the central nervous system were removed intra vitam, and the dog was killed while under anesthesia.

*Histologic Examination*—The Cerebrum. In the large pyramidal cells, most of the extranuclear chromatin was lost, and the cell body was much vacuolated. A few cells were hyperchromatic. There were no exhausted cells. On recutting and restaining, the same changes were found, and in addition there were some cells in which the nucleoli were red instead of blue and were placed eccentrically.

The Cerebellum. Two differential counts of 100 Purkinje cells each were as follows:

	Active Cells, per Cent	Fatigued Cells, per Cent	Exhausted Cells, per Cent
Count 1	56	35	9
Count 2	59	36	5
Normal dog count	71.2	28.1	0.7

The Medulla. The sections were from the level of the fifth cranial nerve. Hyperchromatic cells were present. Most of the cells were well stained, and contained fairly large chromatin granules. In some places, especially in the substantia nigra, the granules were fewer in number and smaller in size. Cells of the tegmental nucleus were present, and showed some changes. Very little change was found in the nucleus of the fifth nerve. On recutting and restaining the findings were practically the same, a larger proportion of hyperchromatic cells being found.

The Cord. The sections were well stained. In some cells, the granules were large but scattered, while in others they were fine.

#### COMMENT

Experiments 3 and 4 present no evidence of any material variation produced by the substitution of scopolamin for morphin, although in Experiment 4 it is difficult to account for the larger percentage of exhausted cells.

#### GROUP 6 EFFECT OF ABDOMINAL TRAUMA ON OTHER ORGANS THAN THOSE OF THE CENTRAL NERVOUS SYSTEM

In a later series of studies than those described thus far, dogs were subjected to like trauma under varying conditions, and sections were taken of various other tissues than those of the central nervous system. The details of most of the experiments in this group were carried out by Dr. R. E. Mosiman and Dr. W. B. Rogers, and the histologic exam-

inations, as in the former experiments, were made by Dr Austin. No differential Purkinje cell counts were made.

EXPERIMENT 1 — *Abdominal trauma under ether* Feb 2, 1914 Under ether anesthesia, vigorous manipulations of the intestines and lower muscles were carried out for three hours.

*Histologic Examination*—Cerebellum The cells were generally fatigued and exhausted, although there were a few hyperchromatic Purkinje cells.

Suprarenal The entire cortex and medulla showed great loss of cytoplasm, the cells being irregular, with eccentric nuclei.

Spleen The lymph spaces were greatly enlarged, the number of nuclei of the cells was apparently decreased.

Testicle This was normal.

Lymph Gland The lymph spaces were distended.

EXPERIMENT 2 — *Abdominal trauma under ether* May 18, 1916 Ether anesthesia was used. Sections of the muscle and liver were taken before the intestinal manipulations were started. Vigorous manipulations of the intestines and peritoneum were carried out for two hours.

*Histologic Examination*—Cerebrum An occasional hyperchromatic and active cell was found. Most of the cells were fatigued, some were exhausted.

Cerebellum There were many hyperchromatic and active cells, some were fatigued, a few were exhausted.

Liver The control section showed a slight loss of cytoplasm. The "shock section" showed a greater loss of cytoplasm, and some vacuolation which was greatest around the central vein.

Suprarenal Great loss of cytoplasm and vacuolation were evident in the outer half of the cortex, there was some loss of cytoplasm in the medulla.

Muscle Normal and "shock sections" were identical in appearance.

EXPERIMENT 3 — *Abdominal trauma under ether* Aug 8, 1916 Under ether anesthesia, intestinal manipulations were performed for three hours.

*Histologic Examination*—Cerebrum No hyperchromatic or active cells were present, nearly all cells were fatigued, some were exhausted.

Cerebellum An occasional hyperchromatic and active cell was found, most of the cells were badly fatigued, some were exhausted.

Liver There was slight loss of cytoplasm in some areas.

Suprarenal Marked loss of cytoplasm and vacuolation were evident in both the cortex and the medulla.

EXPERIMENT 4 — *Abdominal trauma under morphin* April 14, 1914 Three grains of morphin were given just before the experiment was started. Ether was given during the dissection for exposure of the carotid artery for blood pressure tracing. Intestinal manipulations were performed for two hours and twenty minutes.

*Histologic Examination*—Cerebrum There were numerous hyperchromatic and active cells—many fatigued and some exhausted.

Cerebellum A few hyperchromatic cells were present many active, some fatigued, and an occasional exhausted cell.

Medulla All cells were hyperchromatic with large granules.

Spinal Cord Motor cells were active, with small granules, there were no hyperchromatic cells.

Suprarenal There was very slight loss of cytoplasm in the outer cortical cells the medulla was well stained.

Kidney The glomeruli, capsule and tubules were normal

Stomach This was normal, the mucosa was well stained, and the cells were well differentiated

Thymus This was very large and lobulated, with much adenoid tissue, the corpuscles were very small

Spleen This was normal and full of lymphocytes

Lymph Gland This was normal, well stained, contained many lymphocytes, and there was no congestion

Submaxillary Gland This was normal and well stained

Voluntary Muscle This was normal, and the striations were faint

Heart Muscle This was normal

Testicle This was well stained There was no spermatogenesis nor spermatozoa

Lung This was normal

TABLE 8—HISTOLOGIC FINDINGS IN CROSSED CIRCULATION EXPERIMENTS 5 AND 6, GROUP 6

Tissue	Dog A—Traumatized	Dog B—Not Traumatized
Cerebrum		
Experiment 5	No hyperchromatic cells, all fatigued	Some hyperchromatic cells, many fatigued
Experiment 6	No hyperchromatic cells, all fatigued or exhausted	Many hyperchromatic cells, few fatigued
Cerebellum		
Experiment 5	Few hyperchromatic cells, in worse condition than B	Some hyperchromatic cells, many exhausted
Experiment 6	No hyperchromatic cells, all fatigued or exhausted, distinctly worse than B	Occasional hyperchromatic cells, many fatigued
Liver		
Experiment 5	Slight uniform loss of cytoplasm	Marked loss of cytoplasm and large vacuoles
Experiment 6	Old fatty degeneration between lobules, cells almost normal	(Section was missing)
Suprarenal		
Experiment 5	Normal	Normal
Experiment 6	Practically normal	Practically normal

*Comment*—In this experiment, the general appearance of the brain cells was far better than in the case of like trauma under ether alone or with the addition of a small amount of morphin

EXPERIMENT 5—*Abdominal trauma to one of two dogs united by crossed circulation* Jan 25, 1917 Under ether anesthesia, reciprocal anastomosis of the carotid arteries and jugular veins was accomplished in the usual way, and the intestines of one of the dogs were traumatized more or less continually for three hours During this period, the temperature of the traumatized dog fell from 37.4 to 33.7 C or 37 degrees, while the temperature of the untraumatized dog fell only 1.1 degree—from 38.2 to 37.1 C

The animals died within two or three minutes of each other, and sections of the brain, liver and suprarenals of each were taken immediately

The comparative histologic findings are given in Table 8

EXPERIMENT 6—Feb 1, 1917 The details of this experiment were the same as those of Experiment 5 described above The comparative histologic findings are given in Table 8

*Comment*—As in the crossed circulation experiments in a previous group, there is a distinctly worse condition in both the cerebrum and cerebellum of the dog subjected to intestinal trauma than in the untraumatized dog

## SUMMARY OF HISTOLOGIC FINDINGS

1 Physical injury causes changes in the cells of the central nervous system (Figs 1 and 2)

2 The changes in the cells of the cortex and cerebellum are more marked than those in the medulla and cord, and the changes in the medulla are more marked than those in the cord

3 The extent of the changes in the brain cells are in direct relation to the duration and the intensity of the trauma

4 The changes in the brain cells produced by traumatism of an animal under ether anesthesia are many times greater than those produced by approximately equal trauma of an animal under nitrous oxid anesthesia (Fig 3)

5 The brain cell changes produced by traumatism of an animal under ether or nitrous oxid anesthesia are greater than those produced by either anesthetic alone

6 No brain cell changes are produced by traumatism of the distal areas in a dog whose spinal cord has been completely severed (Figs 4 to 6)

7 Shock cannot be transmitted through the blood stream (Fig 7)

8 If a stated blood pressure is maintained by transfusion, brain cell changes will still occur as a result of traumatism

9 A limited series of experiments indicates that, in addition to the central nervous system, only the liver and, to a slight degree, the suprarenals are histologically altered in shock (Figs 8 to 11)

10 The evidence from our histologic studies unfailingly supports the assumption that the essential lesions in traumatic shock are in the central nervous system

D PHYSICOCHEMICAL AND FUNCTIONAL STUDIES  
STUDIES OF THE SUPRARENAL OUTPUT

In three animals, tests of the effect of abdominal trauma on the suprarenal output were made in our laboratory by Dr Hitchings, using Cannon's method. In two instances, no reaction was secured immediately after the application of intense trauma for ten minutes (Fig 12). In another instance, the intestinal manipulations were continued for one-half hour, at the termination of which, the test for epinephrin was negative. The intestinal manipulations were then continued for fifteen minutes more, the blood again giving no reaction to the test for epinephrin. Blood taken after death was negative also. Ether anesthesia was employed throughout these experiments.

## CHEMICAL CONTENT OF CERTAIN TISSUES

Eight cats were subjected, under ether anesthesia, to intestinal manipulations for thirty minutes, at the termination of which time,



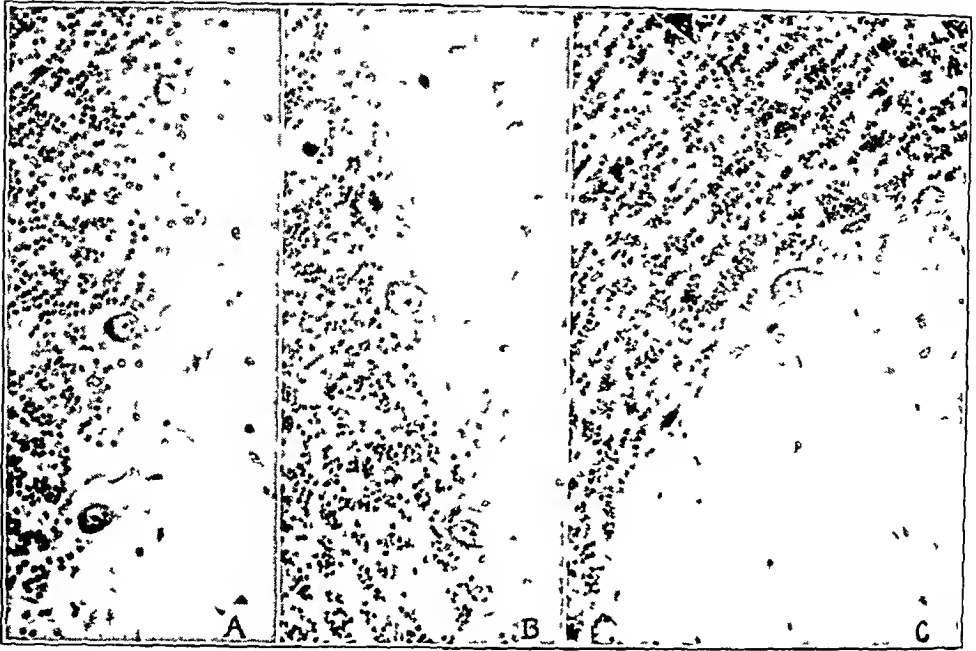


Fig 15—Effect of physical trauma on the cerebellum *A*, section of normal human cerebellum, *B* and *C*, sections of cerebellum of a soldier who died at a casualty clearing station from extensive abdominal wounds (reduced from photomicrographs,  $\times 310$ )

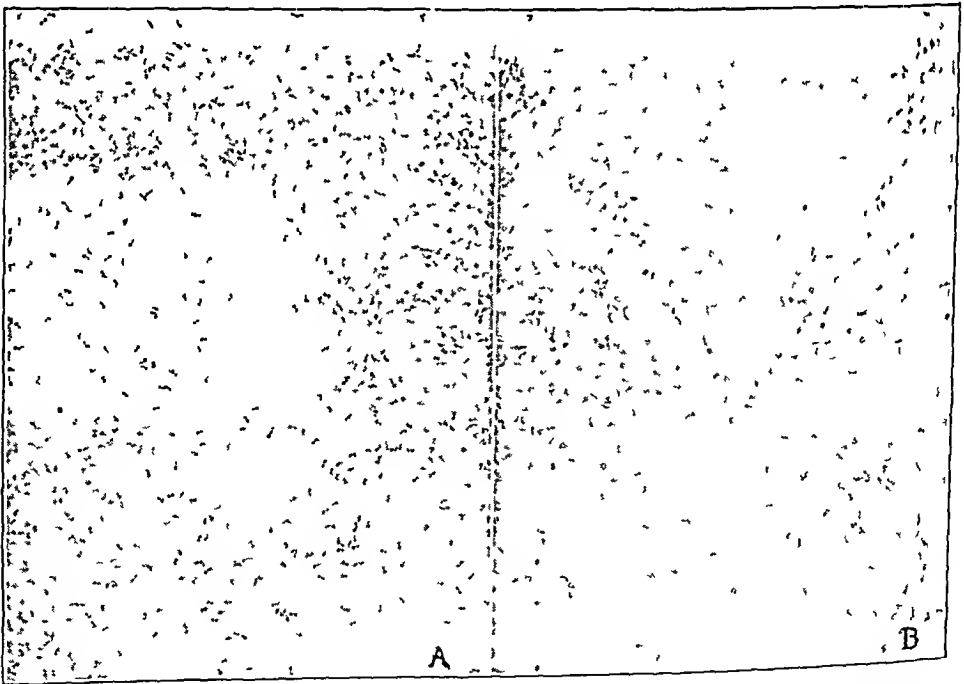


Fig 16—Effect of physical trauma on the liver *A*, section of normal human liver, *B*, section of liver of a soldier who died at a casualty clearing station from extensive abdominal wounds (reduced from photomicrographs,  $\times 120$ )

the glands and tissues were removed. These, with like glands and tissues from normal cats, were sent to Parke, Davis and Company, where assays were made through the courtesy of Dr Houghton and Messrs Briggs, Hamilton and Rowe.

The results of these assays as given in Table 9 demonstrate that, in the traumatized animals as compared with the normal animals (1) the iodine content of the thyroid gland was increased, (2) the epinephrine

TABLE 9—PHYSIOCHEMICAL STUDIES OF THE EFFECT OF PHYSICAL TRAUMA ON CERTAIN ORGANS AND TISSUES

	Thyroid Iodin Content, per Cent	Suprarenals		Liver Glycogen Content per Cent	Muscle Glycogen Content, per Cent	Hypophysis Pituitrin Activity, per Cent of Standard
		Epinephrine Content, per Cent	Epinephrine Activity, per Cent of Standard			
Normal cats	0.01	0.1	5	0.508	0.56	25
Traumatized cats	0.03	0.054	2.7	0.036	0.305	20

TABLE 10—EFFECT OF PHYSICAL TRAUMA ON THE H-ION CONCENTRATION OF THE BLOOD

Experiment 1	Blood from normal dog	7.61, 7.61
	Blood taken forty minutes after intestines had been manipulated for one and three-fourths hours (ether anesthesia)	7.11
Experiment 2	Blood taken seventy minutes after cessation of trauma	6.97, 6.99
	Blood from normal dog	7.48, 7.44
Experiment 3	Blood taken sixty minutes after intestines had been manipulated for one and three-fourths hours (ether anesthesia)	7.19, 7.08
	Blood from normal dog	7.63, 7.63
	Blood taken thirty minutes after intestinal manipulations started	7.31, 7.27
	Blood taken fifty minutes after intestinal manipulations started	7.24
	(The intestinal manipulations continued throughout period)	

content and epinephrine activity were decreased, (3) the glycogen content of the liver and of voluntary muscle was decreased, and (4) the pituitrin activity was decreased.

#### MEASUREMENTS OF H-ION CONCENTRATION AND OF RESERVE ALKALINITY

Three studies of the effect of intestinal trauma on the H-ion concentration of the blood made by Dr M. L. Menten, the results of which are given in Table 10, reveal that, in every instance, the H-ion concentration was markedly increased.

A measurement, made by Dr W. B. Rogers, of the reserve alkalinity by the Van Slyke method disclosed a diminution in the carbon dioxide combining power from 42 c.c. for each hundred cubic centimeters of plasma to 21 c.c. (vein) and 26 c.c. (artery), after manipulations of the intestines for two hours. With ether anesthesia alone for the same period, the reduction was from 46 c.c. to 32 c.c.

In the laboratory of U S Base Hospital No 4 (The Lakeside Unit) in France, Major A B Eisenbrey and Lieut F De Eds made comparative studies of the blood from the longitudinal sinus and from the femoral vein, by Martin's titration method

In these experiments, the preliminary samples of blood were removed under nitrous oxid anesthesia The anesthetic was then changed to ether, and the animals were subjected to intestinal trauma for one-half hour, when samples of blood were again taken

TABLE 11—COMPARISON OF THE RESERVE ALKALINITY OF BLOOD BEFORE AND AFTER INTESTINAL TRAUMA FOR ONE-HALF HOUR

	Before Trauma		After Trauma (One Half Hour)	
	Blood from Femoral Vein	Blood from Longitudinal Sinus	Blood from Femoral Vein	Blood from Longitudinal Sinus
Experiment 1	0 513 0 5	0 445 0 43	0 475 0 47	0 475 0 48
Experiment 2	0 38	0 3055	0 545	0 385
Experiment 3	0 35 0 35	0 325 0 33	0 46 0 45	0 55 0 54
Experiment 4	0 5 0 5	0 425 0 43	0 525 0 53	0 578 0 58
Experiment 5	0 67 0 675	0 445 0 45	0 61 0 555	0 5 0 45

TABLE 12—THE EFFECTS OF SURGICAL OPERATION UNDER NITROUS OXID ANESTHESIA UPON THE H-ION CONCENTRATION OF THE BLOOD (CLINICAL CASES)

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Before operation	7 65	7 65	7 53		7 63	
Nitrous oxid analgesia (descending)	7 60		7 41	7 57	7 46	7 55
At end of one hour on operating table	7 54	7 60	7 26	7 29	7 46	7 50
Nitrous oxid analgesia (ascending)				7 40		7 53
One hour after operation		7 63	7 42		7 53	7 57

The results in five experiments are given in Table 11, which reveals that the blood taken after a half hour of trauma showed a higher alkali reserve in the blood of both the longitudinal sinus and the femoral vein, comparing sinus with sinus, and vein with vein

In each of the other two cases, the alkali reserve of the blood from the longitudinal sinus was increased, the blood from the femoral vein showing a decrease In summary, our H-ion and reserve alkalinity studies appear to show an increased alkali reserve in the earlier stages of shock, with a decreased alkali reserve in the later stages

As a corollary to these experimental determinations may be noted a series of measurements of the H-ion concentration in patients before and after surgical operation under nitrous oxid anesthesia (Table 12)

## ELECTRIC CONDUCTIVITY MEASUREMENTS

Under ether anesthesia, three groups of rabbits were subjected to intense shock-producing manipulations of the intestines for periods of one, of five, and of from thirty to forty-five minutes, respectively. Each animal was killed immediately, and conductivity measurement made of the cerebrum, cerebellum and liver.<sup>6</sup> The average of the measurements of the animals in each group was compared with the average of the measurements of a like number of normal animals which, with the animals subjected to trauma, had been kept for some time under identical conditions in our laboratory. The measurements from the three normals and from the traumatized animals are given in Table 13, and a comparison of the early and late effects of trauma is shown graphically in Figure 13.

TABLE 13—COMPARISON OF THE EARLY AND LATE EFFECTS OF PHYSICAL TRAUMA ON THE ELECTRIC CONDUCTIVITY OF THE BRAIN AND THE LIVER

Date	Length of Trauma	No of Animals	Cerebrum	Average Deviation, per Cent	Percentage Deviation, from Normal	No of Animals	Cerebellum	Average Deviation, per Cent	Percentage Deviation, from Normal	No of Animals	Liver	Average Deviation, per Cent	Percentage Deviation, from Normal
6/11-6/18/19	Normal Group VI	8	00172	1.7		8	00131	1.0		6	00101	1.7	
6/9/19	Trauma, 1 min	5	00189	1.0	-9.8	6	00138	1.3	-5.3	4	00108	1.9	-6.9
6/6/19	Trauma 5 min	3	00175	0.8	+1.7	3	00142	1.9	-8.3	3	00116	6.5	-14.8
1/3-2/19/19	Normal Group III	5	00192	1.6		5	00162	5.3		5	00074	2.2	
1/8-1/10/19	Trauma, 30-45 min	5	00168	2.4	-12.5	5	00154	1.7	-4.9	6	00091	5.5	+22.9

## THERMO-ELECTRIC STUDIES OF TEMPERATURE VARIATIONS IN THE BRAIN AND IN THE LIVER

In order to determine whether or not the variations in the structure and in the electric conductivity of cells, which we have described above, are parts of the same process as that manifested by changes in functional activity, it was necessary to devise some method whereby the functional changes in the cells might be measured in the living animal.

Variations in functional activity indicate variations in oxidation, variations in oxidation are manifested by variations in heat production.

For the accurate measurement of these variations, if present, we devised thermocouples which could be applied directly to the brain, liver or other tissues of the living animal.

<sup>6</sup> Crile, G. W., Hosmer, H. R., and Rowland, A. F. The Electrical Conductivity of Animal Tissues Under Normal and Pathological Conditions. *Am J Physiol* 60: 59-106 (March) 1922.

A description of the arrangement of the apparatus for these studies and a review of the literature pertaining to this method of temperature measurement have been published elsewhere<sup>7</sup> We shall confine ourselves here to a brief statement of our observations of the temperatures in the brains and livers of animals subjected to physical injury

In most instances, contact with the animal under observation produced an immediate alteration in the temperature of the brain In the case of severe trauma, produced by shock-producing manipulations of the intestine, a progressive decrease in the temperature of the brain and of the liver was noted The temperature of the brain usually rose

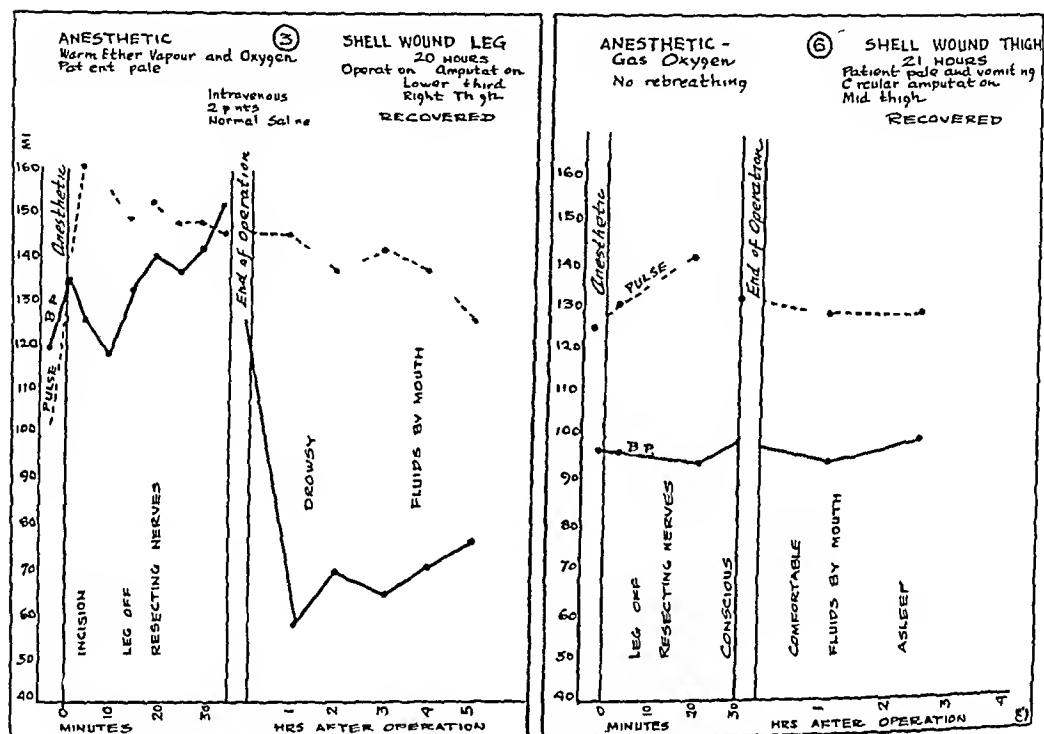


Fig 17—Comparison of the clinical effects of thigh amputation under ether with those of a like operation under nitrous oxid anesthesia (Charts of wounded soldiers treated at Base Hospital, through the courtesy of Capt Geoffrey Marshall)

for an instant on the application of an intense stimulus, such as tearing of the abdominal wall, but there followed an equally abrupt fall, and the tendency was constantly downward

The exposure of the viscera contributed to the precipitate decrease in the temperature of the brain, which will be noted in some of the

7 Crile G W, Hosmer, H R, and Rowland, A F Thermo-Electric Studies of Temperature Variations in Animal Tissues, I General Considerations, Description of Apparatus and Technique, Am J Physiol 62 341-348 (Oct) 1922

charts (Fig 14) In these, the like fall in the temperature of the liver must probably be largely attributed to the direct exposure of the organ

### E CLINICAL EVIDENCE

The clinical observations have been presented in previous volumes and papers, they are seen daily and were observed on a vast scale during the war (Figs 15 and 16)

Of prime significance is the fact that methods of prevention indicated by these studies are successfully protecting our patients from the destructive results of the physical trauma of surgical operations If physical trauma were the only injuring factor present in a surgical operation, its destructive effects could be modified, as our experiments have shown, by the use of local anesthesia and of nitrous oxid-oxygen That exhaustion of the brain is the primary factor in the production of shock from surgical trauma is evidenced daily in the clinic by the protection afforded by these two agents (Fig 17)

A later section of these studies in exhaustion will give further experimental evidence regarding the direct influence of these and other protective and restorative agents

### GENERAL SUMMARY

1 The effects of physical injury, especially of abdominal trauma, have been studied by (*a*) observations of the blood pressure, (*b*) measurements of the constituents of the blood, (*c*) histologic studies, (*d*) measurements of the H-ion concentration and of the alkali reserve of the blood, (*e*) estimations of the iodine content of the thyroid gland, of the epinephrin content of the suprarenals and the epinephrin activity, of the pituitrin activity, of the glycogen content of the liver and of voluntary muscle, (*f*) measurement of the electrical conductivity of the brain and the liver, (*g*) direct measurements of the temperature of the brain and the liver, and (*h*) clinical observations of patients after physical trauma received by accident or in war, or in surgical operations

2 All of these lines of investigation indicate that changes in the central nervous system—primarily in the brain—constitute the fundamental cause of the exhaustion and shock which follow physical trauma

3 The experimental evidence indicates that the liver, and possibly the suprarenals, is linked with the brain in the cycle of exhaustion-producing changes which are initiated by the changes in the brain

4 These studies present no evidence that any primary change in the distribution or constitution of the blood is produced by physical trauma alone When such changes were demonstrated, they were end-effects, not causative factors, of shock or exhaustion

5 A limited group of experiments indicates that, under anesthesia at least, the suprarenals do not respond to the stimuli of physical trauma by any increase in their output

6 The essential cause of exhaustion from physical trauma is identical with that of exhaustion from insomnia, by emotion and by exertion, as presented in the preceding studies in this series

# THE ETIOLOGY OF URINARY LITHIASIS AN EXPERIMENTAL STUDY\*

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In a recent study of the literature on the etiology of urinary lithiasis and closely related subjects, the conclusions reached after careful analysis may be summarized briefly, thus

1 The problem of calculus formation in the urinary tract is one of chemical precipitation. The mechanism which causes the precipitation of urates, oxalates, phosphates, and so forth, in such a way that a fused hard concretion arises, rather than the deposition of individual crystals which maintain a state of isolation in passing through the urinary tract must be determined.

2 Differences in reaction, as determined by the hydrogen ion concentration, and qualitative and quantitative changes in the urinary colloids (such as pigments, mucin, nebecula, albumin, and nucleo-albumin), have been shown to influence the nature of urinary sediments both chemically and physically. The microscopic and gross features of calculi would seem to show that an abnormal variation of these factors is at work in the formation of stone.

3 Race, age, heredity, trauma, occupation, diet, sex, and geographic distribution seem to suggest little with regard to the etiology of concretions, if factors at all, they are probably of secondary importance.

4 The three commonest diseases associated with an increase in the crystalline content of the urine, namely, gout, oxaluria, and phosphaturia, are found far oftener without accompanying calculus deposition than with it. Many observers have assumed that there is a high incidence of lithiasis in such diseases, but have offered little statistical evidence to support their views.

Xanthinuria and cystinuria are necessary to the formation of xanthin and cystin stones, but the frequency with which xanthinuric and cystinuric patients escape calculus formation is problematic.

5 On the whole, clinical evidence points to a local mechanism at work in the kidneys, ureters, or bladder to cause the stones. The frequent occurrence of demonstrable foci of infection in patients suffering from calculus and the almost universal finding of infected kidneys

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\* Abridgment of thesis submitted to the Faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the Degree of Master of Science in Pathology. The work was done in the Section of Experimental Surgery of the Mayo Foundation and the Section of Urology of the Mayo Clinic.



or bladders associated with stone lend weight to the belief that a specific stone-forming infection is at work in most instances. It is conceivable that at times excessive excretion of crystalloid material may reach such a degree that the normal protective colloids of the urine cannot handle the extra burden. Under such circumstances fusion of crystals and calculus formation might take place. Likewise, it is possible that qualitative or quantitative changes in the colloids of the urine may occur without bacterial infection. Such changes might lead to concrement formation even though the urinary crystalloid excretion remains within normal limits.

6 There is little direct evidence to prove that anatomic factors or stasis can initiate the stone-forming process, but their frequent association with calculus makes it seem likely that the stone-forming mechanism may work to better advantage under such circumstances.

The commoner theories of calculus formation were subjected to laboratory experimentation whenever possible, the procedures being guided to a high degree by the preceding studies. The magnitude of such a task is obvious and necessarily prohibitive so far as concerned many details which, though important, were not deemed immediately expedient. Abstracts of experiments are accompanied by typical protocols when necessary to afford detail.

#### SERIES 1 THE EFFECT OF A HIGH CALCIUM DIET ON THE CRYSTALLINE CONTENT OF URINE

A high content of calcium in the diet has long been considered a factor predisposing to lithiasis. For this reason an effort was made to concentrate the calcium salts in the urine of rabbits by administering massive doses of calcium oxalate, chlorid, lactate, and phosphate to normal rabbits, and also to rabbits that had been subjected to a low-grade toxic nephritis by the administration of minute doses of oxalic acid, mercuric chlorid, cantharides, or chloroform.

Feedings 1 and 2 were given on alternate days for the purpose of keeping the urine alkaline. After one week Feedings 3 and 4 were given on alternate days for the purpose of keeping the urine acid. The seven rabbits lived from nine to fifty-four days, the reaction of the urine being fairly well maintained. Aside from an occasional calcium oxalate octahedron, no visible increase in the crystalline content of the urine was noted. Necropsy did not reveal lime deposits or concretions. The intramuscular injections had been poorly absorbed.

Feedings 1 and 2 were given on alternate days for one week, thus keeping the urine alkaline. Feedings 3 and 4 were then given on alternate days to the end of the experiment. The four rabbits lived from ten to twenty-four days, the reaction of the urine being fairly

TABLE 1—EXPERIMENTAL FEEDING OF SEVEN RABBITS (EXPERIMENTS 1 TO 7)

Feeding	Material	Amount	Method of Administration
1	{ Sodium bicarbonate Oxalic acid	{ 1 gm 0.1 gm }	By stomach tube
	{ Calcium lactate Calcium oxalate	{ 0.1 gm 0.5 gm }	Suspension in glucose solution, injected intramuscularly
2	{ Calcium lactate Calcium chlorid	{ 1 gm 1 gm }	In solution by stomach tube
	{ Calcium lactate Calcium oxalate	{ 0.1 gm 0.5 gm }	Suspension in glucose solution, injected intramuscularly
3	{ Sodium benzoate Oxalic acid	{ 1 gm 0.1 gm }	Orally, in capsules and in solu- tion by stomach tube
	{ Calcium lactate Calcium oxalate	{ 0.1 gm 0.5 gm }	Suspension in glucose solution injected intramuscularly
4	{ Calcium chlorid Calcium lactate Hydrochloric acid 1 per cent solution	{ 1 gm 1 gm 20 cc }	In solution by stomach tube
	{ Calcium lactate Calcium oxalate	{ 0.1 gm 0.5 gm }	Suspension in glucose solution, injected intramuscularly

TABLE 2—EXPERIMENTAL FEEDING OF FOUR RABBITS (EXPERIMENTS 8 TO 11)

Feeding	Material	Amount	Method of Administration
1	{ Mercuric chlorid 1:250 solution Acid sodium phosphate Ammonium chlorid Magnesium oxid	{ 1 cc 1 gm 1 gm 1 gm }	By stomach tube
	{ Calcium lactate Calcium phosphate	{ 0.1 gm 1 gm }	Suspension in glucose solution, injected intramuscularly
2	{ Calcium chlorid Ammonium chlorid Hydrochloric acid 1% solution Magnesium oxid	{ 1 gm 1 gm 20 cc 1 gm }	In solution and suspension by stomach tube
	{ Calcium lactate Calcium phosphate (neutral)	{ 0.1 gm 1 gm }	Suspension in glucose solution, injected intramuscularly
3	{ Sodium bicarbonate Acid sodium phosphate Magnesium oxid Ammonium chlorid	{ 1 to 3 gm 0.1 gm 1 gm 1 gm }	In solution and suspension by stomach tube
	{ Mercuric chlorid, 1:250 solution Calcium lactate Calcium phosphate	{ 0.5 cc 0.1 gm 1 gm }	Injected intramuscularly Suspension in glucose solution, injected intramuscularly
4	{ Calcium chlorid Calcium lactate	{ 1 gm 1 gm }	In solution and suspension by stomach tube
	{ Calcium lactate Calcium phosphate	{ 0.1 gm 1 gm }	Suspension in glucose solution, injected intramuscularly

well maintained. A moderate degree of albuminuria was noted. No visible increase in the crystalline content of the urine was observed. Necropsy did not reveal crystalline deposits or concretions.

Here forced feeding of materials from which ammonium magnesium phosphate is derived was made in an endeavor to cause deposition of triple phosphate. Mercuric chlorid poisoning is often associated with calcium deposit in the renal tissues, hence the value of the negativity of this experiment may be emphasized.

*Experiments 16 to 20*—Five rabbits were fed as in Experiments 8 to 11, with the exception that 0.1 to 0.5 c.c. of chloroform was fed instead of mercuric chlorid. Chloroform was used because of its action on the renal epithelium. The five rabbits lived from eight to nineteen days. The visible crystalline content of the urine was not increased. Necropsy revealed marked degenerative change in the hepatic and renal epithelium. No lime deposits or urinary concretions were noted.

*Experiments 21 and 22*—Two rabbits were fed as in Experiments 8 to 11, with the exception that 0.1 minim of tincture of cantharides was substituted in the place of mercuric chlorid. Cantharides was used because of its nephrotoxic effect. The two rabbits lived twenty-one and ten days, respectively. The visible crystalline content of the urine was not increased. Necropsy revealed degenerative changes in the renal and hepatic epithelium but no crystalline deposits or concretions.

*Comment*—Forcing lime salts in massive doses does not cause visible increase in the crystalline content of rabbit's urine. These experiments are in harmony with the views of pharmacologists that an increased ingestion of calcium salts will not lead to a significant increase of calcium in the urine. This is good evidence against a "hard water" or "lime soil" factor in the etiology of stone.

## SERIES 2 THE FORCED ADMINISTRATION OF OXALIC ACID AND ITS DERIVATIVES

Ebstein<sup>1</sup> had shown that uric acid administered orally to rabbits and dogs is destroyed in the metabolism, but it had long been known that the administration of oxalic acid would cause the appearance of calcium oxalate in the urine. Therefore, in different groups of animals, oxalic acid, sodium oxalate, and ammonium oxalate were fed in sublethal doses.

<sup>1</sup> Ebstein, W., and Nicolairer, A. Ueber die experimentelle Erzeugung von Harnsteinen, Wiesbaden, Bergmann, 1891, pp. 149, Ueber die Ausscheidung der Harnsaure durch die Nieren Arch. f. path. Anat. **143**: 337-368, 1896. Ueber die Wirkung der Oxalsaure und einiger ihrer Derivate auf die Nieren, *ibid.* **148**: 366-388, 1897.

Two rabbits (Experiments 25 and 26) were fed 0.4 gm of oxalic acid and 0.4 gm of acetamid, daily, by stomach tube. As the feeding of diamido-oxalic acid had been shown by Ebstein to produce concretions, it seemed best to exclude the possibility of the amid group as a factor in concrement production. The two rabbits lived twenty-four and thirty-eight days, respectively. A moderate number of calcium oxalate crystals was noted daily in the urine. These crystals were always single, of the perfect octahedral type, and showed no tendency toward coalescence or fusion.

In Experiment 25, at necropsy, deposits of white material were found in the straight tubules in the renal pyramid. When scraped with the knife and examined microscopically these proved to be made up of calcium oxalate crystals of the octahedral type, without tendency toward fusion. Both animals showed slight vascular injection of the kidneys and epithelial degeneration in the tubules. No deposits or concretions were noted.

Two rabbits (Experiments 13 and 14) were fed 0.5 gm of ammonium oxalate, daily. One rabbit (Experiment 27) was fed 1 gm of ammonium oxalate and 1 gm of acetamid, daily. The animals lived forty-seven, ten, and fifteen days, respectively. No visible increase in crystalline content of the urine was noted aside from an occasional calcium oxalate octahedron. Necropsy revealed slight nephritis but no crystalline deposits or concretions.

One rabbit (Experiment 15) was fed 0.5 gm of sodium oxalate every two days, it died after forty-six days. A moderate number of calcium oxalate crystals of the perfect octahedral type were noted daily. These did not show a tendency to fusion. Necropsy revealed the kidney contracted with nephritis. No lime deposits or concretions were found.

### SERIES 3 EFFECT OF ADMINISTRATION OF BUTYL OXALATE

Inasmuch as the oxaluria produced in Series 2 was not apparently intense, it was decided to feed an ester of oxalic acid in the hope that it would be less toxic than soluble oxalates, as it would furnish a lower concentration of oxalate ions. Ethyl oxalate, when given intramuscularly in doses of 0.5 c.c. or more, killed the animals almost immediately.

*Experiments 28 to 33*—Butyl oxalate was injected intramuscularly into six rabbits in doses of from 0.5 to 1 c.c., daily. In several instances sodium oxalate was fed simultaneously in doses of 0.4 gm, in capsules, daily. The rabbits lived from four to nine days. All developed an intense oxaluria. In all the experiments except Experiment 28, the calcium oxalate crystals were perfect octahedrons, showing no tendency toward coalescence or fusion.

In Experiment 28, after receiving butyl oxalate and sodium oxalate, daily, for six days, the animal died spontaneously. Marked oxaluria with dumb-bell shaped crystals and atypical octahedrons was noted. At necropsy marked distention of the intestines and injection of the mucosa were noted. The bladder was congested and distended and contained about twenty small smooth white stones about 1 by 2 mm in diameter. On chemical examination these proved to be calcium oxalate. As this was the first experiment of the series, cultures were not taken, and sections of the tissues were not made. The kidney appeared slightly injected but otherwise normal. All efforts to repeat the experiment proved futile.

*Comment*—The association of an atypical crystalline oxaluria with formation of concretions was noted in one instance, while the remaining animals consistently showed a typical octahedral form of calcium oxalate in the urine with no concrement formation. This suggests that a change in crystalline form may be related to concrement formation.

#### SERIES 4 THE RESULT OF PLACING AN ORGANIC NUCLEUS IN THE RENAL PELVIS OF THE RABBIT

The presence of organic nuclei, such as fragments of epithelium and disintegrating tissue, having been observed in many calculi, it was decided to determine the effect of placing pieces of tissue into the pelvis of the rabbit's kidney.

*Experiments 102 to 105*—In four rabbits under ether anesthesia and aseptic technic, the left kidney was removed through a lumbar incision, a wedge-shaped portion of the renal pyramid, not quite large enough to fill completely the cavity of the pelvis, was excised. This was placed gently in the renal pelvis, the kidney carefully sutured with No. 00 plain catgut, and the incision closed in layers. The animals lived from six to 121 days, they were killed after the longer periods. In all cases at necropsy the piece of tissue was found lying in a pool of urine and undergoing disintegration. In Experiment 102, when the animal was killed, the pelvis was found clear, no trace of the tissue being seen. There was no evidence of calcareous deposit, and, except for the operative scar, the kidney appeared normal. A culture was negative for bacterial growth.

In view of this negative result, bits of muscle and fascia from the lumbar region were introduced through a nephrotomy wound into the left renal pelvis of several rabbits. The kidney and the incision were closed. Several of the animals are still alive. In Experiment 108 the animal was killed 122 days after operation. The disintegrating muscle tissue was found to be impregnated with lime salts lying in a pool of purulent material, the kidney showed moderate hydronephrosis. A

culture of the pus yielded a gram-positive bacillus. One half of the muscle tissue was firm and stony, while the other half was soft and gritty.

*Comment*—No conclusions can be drawn from a single experiment, but it would seem that foreign bodies or organic nuclei in themselves will not initiate stone formation. If retained long enough, however, they may form a point of lowered resistance for bacterial invasion by irritation. Under such conditions they become impregnated with crystalline material which may develop into true calculi. In the cases in which bits of renal pyramid were enclosed in the pelvis, cultures were negative. Infection was not determined by culture from several animals that died within a week after the insertion of the muscle tissue into



Fig 1 (Experiment 58)—Bilateral lithiasis in a rabbit fed oxamid daily for seventeen days, larger masses lie behind the free margin where the calices are attached to the renal parenchyma (Fig 13)

the pelvis of the kidney. Filling the pelvis with bits of muscle tissue is equivalent to the introduction of stasis of high degree and also to increasing markedly surface duplication in the pelvis. Hence it would seem that the failure to secure a deposit of crystalline material in the absence of infection is a strong point against a purely mechanical theory of stone formation.

#### SERIES 5 A STUDY OF THE FORMATION OF OXAMID CALCULI

The formation of concretions in the urinary tract after the administration of oxamid to animals had apparently been regarded as a medical curiosity since the time of Ebstein, although subsequently Tuffier<sup>2</sup> and

<sup>2</sup> Tuffier, M. Lithiase urinaire artificielle, Bull Soc anat de Paris 68 49-53 1893

Rosenbach<sup>3</sup> had carried out confirmatory experiments. Little or no mention of the process occurs in current literature, especially in this country. The fact that oxamid would form urinary concretions had been confirmed in Mann's laboratory by J. R. McVay, who had fed two dogs on oxamid for several months. Hence it was decided to study this phenomenon more in detail with the hope that the observations might give an insight into the genesis of calculi seen clinically.

Fourteen rabbits (Experiments 56 to 69) were fed oxamid orally in capsules in doses of 0.4 to 0.8 gm, daily. Five dogs (Experiments 118 to 122) were fed oxamid in doses of 2 gm, daily, by the same method. The results are given in Table 3.

TABLE 3—EXPERIMENTAL FINDING OF FOURTEEN RABBITS AND FOUR DOGS

Rabbits Experiment	Duration of Life, Days	Oxamid Fed, Gm	Cause of Death	Sediment, Concretions, and Location Found at Necropsy
56	10	8	Coccidiosis	Two minute concretions in right pelvis, sand in left
57	10	8	Nephritis	A few particles of sand in left pelvis, stone in the bladder
58	17	11	Nephritis	Minute concretions in both pelves (Fig 1)
59	7	4.8	Nephritis	Fine sand in right pelvis, left clear
60	18	12.8	Nephritis	Fine sand in calices of both sides
61	26	13.4	Nephritis	No deposit
62	17	9.6	Nephritis	Right pelvis clear, a few flecks of sand in left
63	26	9.6	Pneumonia	No deposit
64	10	8	Pneumonia	A few flecks of sand in right pelvis, left clear
65	41	28	Accidental	Slight amount of fine sand in both pelves
66	7	10	Accidental	No deposit noted
67	20	28	Ether	Small stone in right ureter and sediment in right pelvis, slight deposit in left pelvis
68	20	28	Ether	A few flecks of sand in right pelvis, left clear
69	25	20	Pneumonia	Right pelvis clear, kidney shows crystalline infarcts in left pyramids, a few small stones
Dogs Experiment	Months and Days			
118	9 5	130	Ether	No deposit noted *
119	5 10	140	Accidental	Stones in right kidney, left clear, hydro nephrosis
120	7	324	Nephritis	Stones in both kidneys and ureters
121	36	40	Pneumonia	Small stones in both kidneys
122	14	20	Pneumonia	Crystalline infarcts in right kidney, few small stones in right pelvis, left clear

\* Oxamid not given three months before death.

After an interval varying from a few days to several months, yellow crystalline material, varying from traces of fine sand to concretions 1 cm in diameter, appeared irregularly in the kidneys, ureters, or bladder of about 75 per cent of the animals. Concretions of sufficient magnitude to be considered stones occurred in about 50 per cent of the animals. Smaller deposits were the rule. The deposit often was bilateral, with no preference as to side. The larger concretions showed definite radial striations and concentric markings suggestive of deposi-

3 Rosenbach. Kritischer und experimentelle Beiträge zur Frage der Entstehung der Nierensteine, *Mitt. d. Grenzgeb. d. Med. u. Chir.* 12: 630-656, 1911.

tion in layers (Fig 2) The deposits were more often multiple than single Five animals (about 25 per cent) did not have deposits after long feeding The passage of sand and smaller concretions was found in all animals from which twenty-four hour specimens of urine were collected by means of metabolism cages Cultures from the kidneys and from the urine were consistently sterile The animals often lost weight, especially on long feeding All showed variable toxic degenerative changes in the epithelium, and increase in the vascular injection of the liver and kidneys The liver especially was firm, with an increase in fibrous tissue in the experiments of longer duration No intracellular crystalline deposits or stones in the renal parenchyma were noted Albuminuria, without pus, casts, or red cells, was a constant finding In several instances, an atypical reduction of Fehling's solution was observed, but a true glycosuria was never demonstrated

The reaction of the urine, as roughly determined by litmus, seemed not to affect the process, some of the animals had acid urine, others



Fig 2—Fragment of an oxamid stone showing radial markings and the deposition in concentric layers,  $\times 200$

alkaline Three rabbits (Experiments 78 to 80) were fed 1 gm of sodium benzoate, daily, with the oxamid, the urine was usually acid, two had a moderate amount of oxamid deposition Four rabbits (Experiments 81 to 84) were fed 1 gm of magnesium oxid, daily, with the oxamid, the urine was consistently alkaline One of the animals developed definite concretions in the kidney and others showed traces of sand

Extending the duration of feeding, increasing the daily dosage of oxamid to 10 gm (Experiments 67 to 76), varying the fluid intake in twenty-four hours (Experiments 69 to 75) seemed not to produce, within wide limits, quantitative change in the amount of oxamid deposition found in the urinary tract at necropsy (On complete withdrawal of water the excretion of oxamid decreased as the experiment approached termination) Toxic nephritis produced by mercuric chlorid (Experiments 85 and 86) likewise had no apparent effect on the process



*The Crystallographic Features of Oxamid Lithiasis*—In a former publication<sup>4</sup> it was noted that Rainey,<sup>5</sup> Ord and Shattock<sup>6</sup> and others have suggested a relationship between calculi and abnormal crystalline forms which had occurred when the crystalline material was deposited from gelatinous or colloidal mediums. Within from twenty-four to thirty-six hours after the feeding of oxamid to animals, abnormal crystals appeared in the voided urine. These were variously pigmented, the color ranging from a light brown to a brownish black. The crystals were doubly refractile in the dark field where the brownish-black color was found to be really a deep orange. The morphology of the crystals can be appreciated readily by referring to Figures 3 to 6. Many of the crystals were isolated and single. Others were clumped together somewhat after the manner of agglutinated blood cells. However, dotting the



Fig 3 (Experiment 61)—Different phases of crystalline morphology in sediment of a rabbit fed oxamid, simple crosses, crosses with the interbranchial spaces partly filled, square forms, and spherical forms,  $\times 200$

field in numbers varying with the specimen were masses of crystals in every degree of coalescence and fusion. There were, in the different specimens, a number of morphologic varieties of crystals. All seemed to be developed from a simple crosslike form (Figs 2 and 3). There were crosses with smooth arms and crosses with rough pointed arms,

4 Keyser, L. D., and Braasch, W. F. The Etiology of Urinary Lithiasis. Collective Review, Surg., Gynec. & Obst., Internat. Abst. Surg. **34**: 1-10, 1922.

5 Rainey, G., quoted by Ord, W. M. and Shattock, S. G. On the Microscopic Structure of Urinary Calculi of Oxalate of Lime, Tr. Path. Soc., London **46**: 91-132, 1895.

6 Ord, W. M., and Shattock, S. G. Footnote 5, second reference. Shattock, S. G. On the Microscopic Structure of Uric Acid Calculi, Proc. Roy. Soc. Med. **4**: Path. Sect. 110-146, 1911.

crosses with the interbranchial spaces roughened and partly filled out, squared forms which seemed to be crosses with the interbranchial spaces entirely filled, and, finally, spheres, rough and smooth on their surfaces. These seemed to be a rounded variety of the squared form and the end-product of development of the cross. The perfect smooth sphere appeared umbilicated and radially striated (Figs 5 and 6). The size of the crystals varied from microscopic dust to crystals from 40 to 50 microns in diameter. All the varieties of crystal form were found in states of fusion to some degree, but in this connection several features

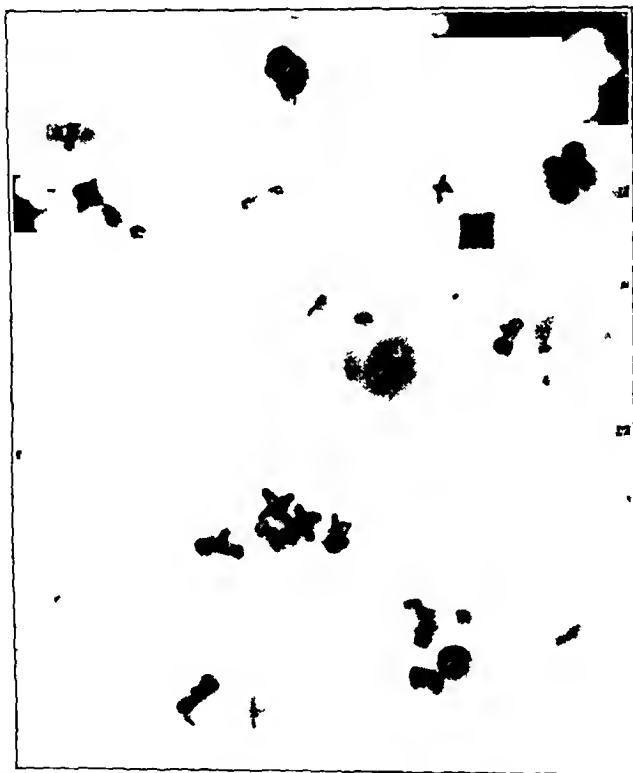


Fig 4 (Experiment 61) —Little tendency to fusion of crystals in urine of a rabbit fed oxamid, at necropsy there was no deposit in kidneys or bladder,  $\times 150$

were noted early and were confirmed by a daily study of urinary sediments from many animals.

There was a tendency for all the forms to coalesce and fuse, but this was greater the more nearly the crystal approached the spherical form. Likewise, the smaller the crystal and the lighter its pigmentation the more often was it found fused with other crystals. The converse was also true. The closer the crystal approached the cross form, the larger it was and the greater its pigmentation, the greater were its chances of being isolated and unfused with other crystals.

Smaller concretions found in the kidney or passed in the urine were found to be made up of crystals of the type just described. In the larger concretions the individuality of the crystals was found in some degree to be lost, but even here on crushing the stone, particles resembling crosses and spherical forms were observed (Fig 7)

Every animal fed on oxamid passed almost all the different morphologic varieties of crystal types, but there was a great tendency for one type or the other to predominate. Depending on this, to some degree, was the likelihood of finding calculi in the kidneys at necropsy. Putting this in another way, it was noted that animals with urine in which small, light-pigmented, smooth or rough spheres predominated would show

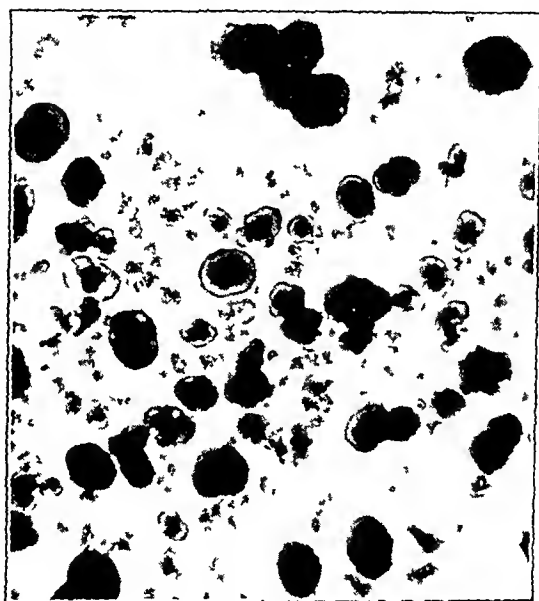


Fig 5 (Experiment 68)—Large smooth spheres showing a tendency to remain isolated. From the urine of a rabbit fed oxamid,  $\times 100$

larger particles of sand in their twenty-four hour specimens, and the deposits found at necropsy would be of the larger, harder type. However, the animal with a predominance of large, dark-brown spheres or crosses alone (associated with few spheres in the microscopic field) would pass only finer particles of sand and would present only fine grains of sand or smaller soft concretions in the urinary tract at necropsy. Thus there seemed to be some relationship between the type of crystal and the size and kind of calculus formed.

*The Chemistry of Oxamid Its Reactions in Urine The Chemistry of Oxamid Stones*—A rather superficial study of the chemistry of oxamid and its reactions in vitro in the urine of normal animals and of human beings has given some results which appear to me especially

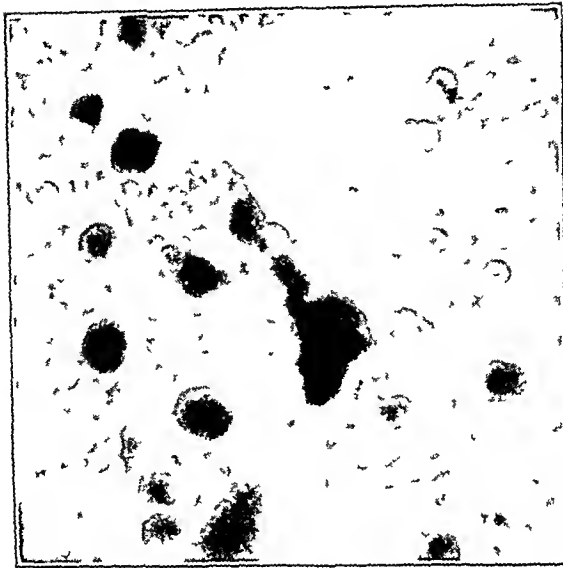


Fig 6 (Experiment 68)—Agglomerations of small, light colored crystals from urine of a rabbit fed oxamid, the larger dark crystals tend to remain isolated,  $\times 100$



Fig 7 (Experiment 68)—A large agglomeration or beginning calculus composed of small spheres and crosses in urine of a rabbit fed on oxamid,  $\times 100$

enlightening in their relationship to the formation of oxamid stone. Oxamid is the diamid of oxalic acid, having the formula  $\begin{array}{c} \text{CONH} \\ | \\ \text{CONH} \end{array}$ . While insoluble in cold water, it goes into solution slowly in boiling water and is gradually hydrolyzed by further boiling to ammonium oxamate and later to ammonium oxalate. Acids or alkalis hasten this hydrolysis. As prepared synthetically by treating an oxalate ester with ammonia, it consists of small irregularly rhomboidal, fissured, translucent, colorless crystals which at times show split and roughened ends (Fig 8).

Oxamid stones, as has been noted, show all degrees of structure from fused aggregations of crystals, individual units of which may be



Fig 8—Crystals of pure oxamid synthetically prepared,  $\times 300$

distinguished on crushing and examining under the microscope, to more solid, completely fused forms in which the identity of the individual crystals is almost, if not quite, lost.

These concretions give the reactions of oxamid, yielding ammonium and oxalate ions on prolonged boiling in water or on dissolving in acid or alkali. They also contain an organic pigment material the identity of which has not yet been established.

*Effect of Urine in Vitro upon Morphology of Oxamid Crystals—* Synthetic oxamid heated with urine of human beings dissolves at from 90 to 100 C in an average quantity of 50 mg to 10 cc of urine. Part of it is undoubtedly hydrolyzed and is not reprecipitated on cooling.

However, some of it is reprecipitated, and this precipitate examined microscopically gives a surprising result. The crystals have become pigmented and have assumed the forms which we have noted in the crystals passed in the urine of animals fed on oxamid. Also there is a corresponding visible diminution in the pigmentation of the urine from which the crystals have been precipitated. All types of oxamid stone-forming crystals have been noted under such conditions from the simple cross to the sphere (Figs 9 and 10).

If the artificially prepared stone-forming crystals or the sediment from the urine of oxamid-fed rabbits is boiled with water, a clear pigmented solution is obtained. If this solution, while hot, is filtered several times through a heated charcoal filter, the pigment and possibly

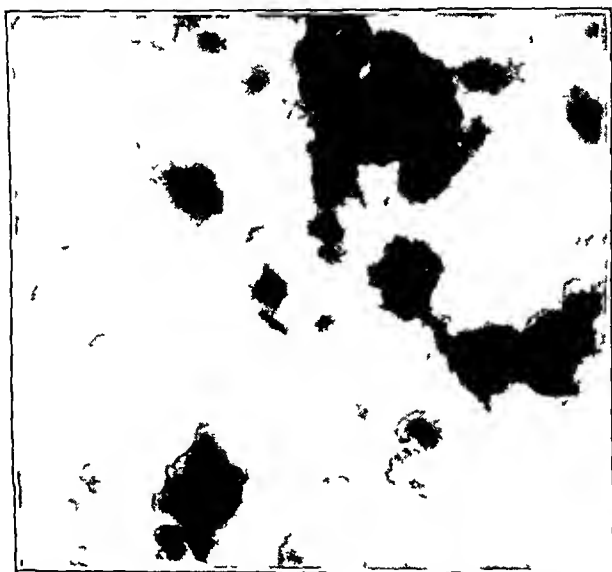


Fig 9—Deposit obtained when synthetic oxamid is dissolved in boiling urine and allowed to precipitate on cooling. The crystals are the developing-cross type, they are pigmented and show marked tendency to fuse into small agglomerations. This sediment is indistinguishable from that in the urine of rabbits fed on oxamid (Fig 7),  $\times 300$ .

other organic colloids are removed. If this is done from ten to fifteen times, the precipitate obtained on cooling comes to assume an entirely altered form. The crystals are colorless and approach very nearly the form of synthetic oxamid crystals.

*Formation of Fusing Oxamid Crystals from Urine in Vitro*—An experiment which seemed to answer the question with regard to the process of the formation of oxamid stone consisted of repeated precipitation of increments of oxamid from the urine of human beings or of animals into the same test tube over a period of days thus obtaining

fusion of crystals Small concretions have been produced which microscopically and chemically, judged by simple tests, resemble small oxamid concretions found in the urinary tract of animals fed with the drug (Fig 11)

*Comment*—The process that takes place in the urinary tract of the animal may be repeated in the test tube, and, further, it is possible to extract, by a sort of fractional absorption, the pigment material from the crystals deposited by oxamid-fed animals, under which conditions a reversion to a simpler crystalline form takes place Whether the pigment alone is responsible for the change, or whether there are other organic materials present, has not been determined However, one conclusion may be held as established The oxamid concretion is the product of a normal colloidal mechanism of the urine, in other words, oxamid being secreted into the urine of animals is precipitated so that a loose physicochemical union with organic materials (probably normally present in the urine) takes place As a result of this unstable union the crystalline form is changed and individual crystals tend to coalesce with one another and become fused I have seen this process in every stage, both in the test tube and in the urine of oxamid-fed animals It speaks emphatically for a colloidal precipitation mechanism in the formation of concretions

The action of normal urine is specific so far as causing fusion of oxamid crystals is concerned This is certainly not the case with crystals of oxalates, urates, and so forth, passed normally by human beings The urinary colloids tend to keep these crystals separate, unfused, and isolated under normal conditions But oxamid is a crystalline material foreign to the normal urinary tract, and the only crystalloid known that can be concentrated in the urine in massive amounts over an extended period of time by feeding The oxalate experiments most nearly approached this, but oxaluria was not obtained in any degree comparable with oxamiduria Once by forcing the dosage of butyl oxalate, abnormal crystals and concretions were obtained, but this experiment could not be repeated

That the sole factor is not the intensity of the oxamiduria is shown by the fact that the animals formed concretions in a short time, and with small doses Within wide limits the dosage or duration of feeding seemed to play little part Hence it must be assumed that the urine is unable to handle oxamid excretion The very colloids that enable it to carry in solution uric acid, oxalates, phosphates, and so forth, may cause it to throw the foreign oxamid from solution in the form of crystals in all states of fusion

This conception of the formation of oxamid stone differs entirely from that of Ebstein, who believed that the oxamid was retained in the cells of the straight tubules of the kidney and that its deposition around

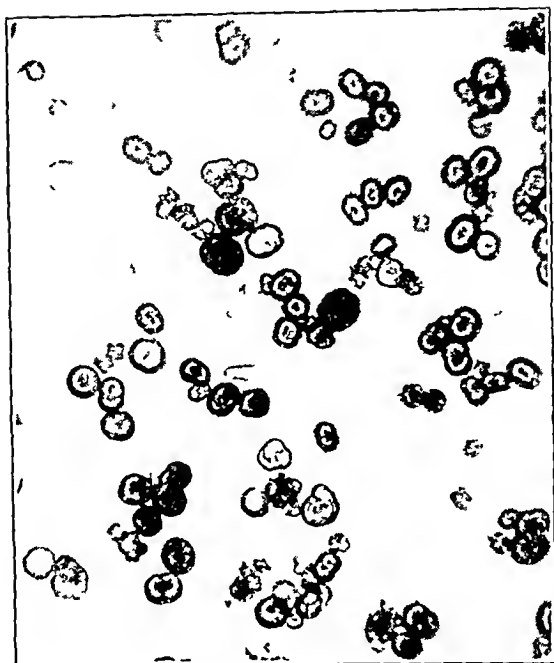


Fig 10—Oxamid crystals deposited in vitro from urine in which the synthetic chemical was dissolved by boiling, showing the perfect smooth sphere and no tendency to fusion,  $\times 200$

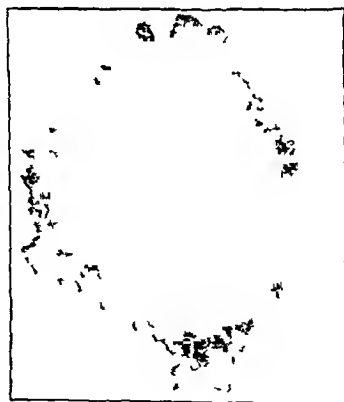


Fig 11—A small oxamid concrement formed, in vitro, by repeatedly precipitating oxamid from human urine. This is a dense form indistinguishable from particles shown in Figure 7,  $\times 50$



these dying cells gave origin to stones. In this investigation intracellular deposits of oxamid in microscopic sections, either with fresh frozen tissue, with frozen fixed tissue, or with paraffin sections, were not seen, neither was epithelial debris impregnated with oxamid noted. Ebstein probably paid more attention to the toxic nephropathy than to the crystallography of oxamid in urine and to this may be attributed the difference in results.

The deductions made for the oxamid concrement formation are obviously entirely in harmony with the work of Rainey, Ord and Shatlock, Fowler,<sup>7</sup> Schade,<sup>8</sup> and with clinical experience with urinary, biliary, and other concrements.

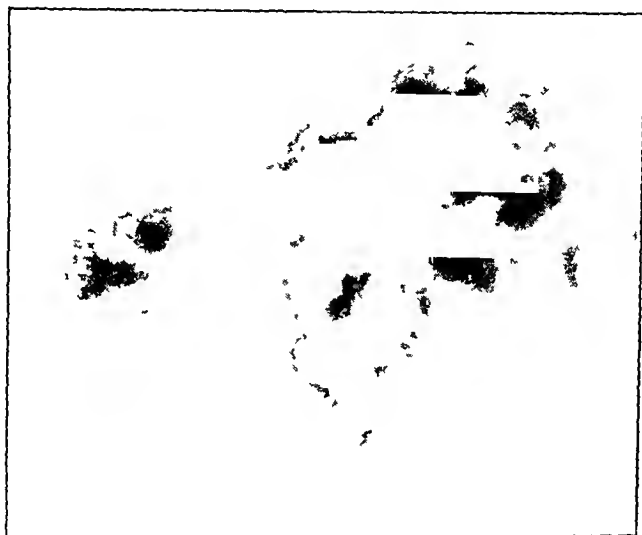


Fig 12 (Experiment 68) —A small crushed concrement in the urine of a rabbit fed oxamid. It consists of small light colored crystals which have coalesced and fused,  $\times 100$ .

#### SERIES 6 A STUDY OF ANATOMIC OR MECHANICAL FACTORS IN THE PRODUCTION OF OXAMID CALCULI A POSSIBLE CLINICAL ANALOGY

After the type of mechanism fundamentally at fault in the production of oxamid calculi had been established, by analogy it was suggested that an abnormal colloidal mechanism in the urine is at work primarily in the formation of concrements seen clinically. Therefore, it became a matter of immediate interest to see how anatomic or mechanic factors would alter the picture, thus throwing light on the reason why stasis, diverticula, organic nuclei, and duplication of surfaces are so often associated with stone, but are also more often unassociated.

<sup>7</sup> Fowler, H. A. The Microscopic Structure of Urinary Calculi of Oxalate of Lime, with Special Reference to the Spiculated Variety, Johns Hopkins Hosp Rep **13** 557-569, 1906.

<sup>8</sup> Schade, H. Beiträge zur Konkrementbildung. I. Zur Entstehung der Harnsteine, München med Wchnschr **56** 3-7, 77-80, 1909.

It should be recalled that only 50 per cent of the animals presented stones at necropsy, and 25 per cent showed no trace of oxamid deposit. Two animals fed for as long as twenty-six days showed no deposit, another fed for six months died three months later. No oxamid deposit was found. It should also be recalled that undoubtedly most of the small fused masses of oxamid crystals are washed on and voided with the urine. Furthermore, every animal fed on oxamid presented sand in the urine at some time or other, while in all states of fusion crystals were consistent, the degree of fusion depending on the crystal type predominant. What then causes the retention of the precipitate that is

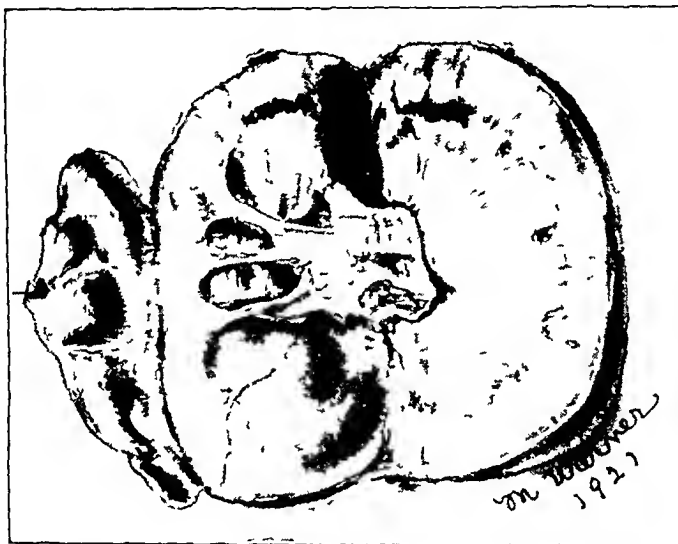


Fig 13 (Experiment 121) —Kidney of dog fed on oxamid showing how the calices are attached to the renal parenchyma in kidneys of the dog and rabbit. The little pockets behind the free margins are the first sites of oxamid deposition.

to grow to the larger stone? Obviously, stasis, diverticula, and surface duplication, as powerful accessory factors in holding back the fusing crystals, are to be considered. In proof of this conception, so far as it relates to the oxamid calculus, the following observations are offered.

1. The first site of deposition of oxamid in the kidney of the dog or rabbit was invariably in the ramifications of the calices, along the line of attachment of the pelvis to the renal sinus. In the rabbit and dog, there is a tiny pocket behind the cusp of the free margin of the calix (Fig 13) in which the concretions were usually found. This is duplicated surface and a point where the normal urinary stream and the musculature of the pelvis probably exert less force in washing crystalline material onward. The tendency of smaller urinary concretions in human beings to lie in the minor calices should be recalled in this connection.

2 (Experiments 91 and 92) Under ether anesthesia and with aseptic technic the left kidney of the rabbit was delivered through a lumbar incision and the renal pelvis exposed. With a fine needle, twenty punctures of the pelvis were made in different areas, care being taken to pierce through and through each time. The bleeding was controlled, the kidney replaced, and the wound closed.

On feeding oxamid to two animals thus treated, an excess of deposit of oxamid and large concretions were found on the left or traumatized



Fig. 14 (Experiment 96)—Marked deposit of oxamid in left kidney of a rabbit fed oxamid nine days as the result of low-grade stasis caused by rubber band around the left ureter. The untreated right kidney is clear.

side, on the untreated right side, no deposition was found in either instance. Here the pelvis was roughened and produced a minute duplication of surfaces, in all probability with microscopic diverticula. Cultures from the kidneys of both of these animals were entirely negative.

3 In order to determine the effect of hydronephrosis and stasis alone, a rubber band was placed around the left ureter so as to constrict it slightly (Experiment 93). The animal was fed 0.8 gm of

oxamid, daily, for eight days. At necropsy hydronephrosis on the left side without oxamid deposit was found. This was also found to take place in several preliminary experiments, which were performed in trying to establish the technic. Hence it was concluded that the ureter on the left side had been constricted to such an extent as to interfere with the pressure equilibrium of urinary secretion, thus, neither the oxamid nor other material had been secreted on that side. The technic was then modified. A left abdominal incision was made, the left ureter



Fig 15 (Experiment 90)—Kidneys of a rabbit fed oxamid, showing the formation of an oxamid calculus around an organic nucleus or foreign body (muscle tissue), previously placed in the left renal pelvis. A striking example of the role played by stasis, duplication of surfaces, and minute diverticula. The right untreated kidney is clear.

exposed, and a rubber band placed snugly around the ureter. No effort was made to constrict the ureter. The periureteritis and swelling which took place in consequence of the presence of the foreign body (rubber band) was depended on to constrict the ureter slightly. On feeding oxamid to rabbits thus treated (Experiments 94 to 96), stones and a marked increase in deposition of sand on the treated side were obtained.

consistently in a few days. On the untreated right side only a few flecks of oxamid were found in any instance. One animal (Fig 14) had been fed only nine days. The treated left side was filled with sand and minute concretions. The untreated right side was clear. This is a striking demonstration of the rôle which stasis plays in the retention of fusing oxamid crystals and in the growth of oxamid stones.

4 In Experiment 97 the left kidney was opened with a nephrotomy incision. A piece of blood vessel silk was placed on the cut surface, running from the tip of the pyramid to the cortex. The free end was allowed to remain in the pelvis of the kidney. The animal was fed 0.8 gm of oxamid, daily, for twenty-nine days. At necropsy the left kidney was filled with several small stones and the thread was encrusted with a deposit of oxamid. The right untreated kidney also contained deposit but much less than the left.

*Experiments 88 to 90*—Under ether anesthesia the left kidney was exposed through a lumbar incision and a nephrotomy performed. Bits of muscle and fascia were placed in the renal pelvis and the incision closed. Three rabbits thus treated were fed on oxamid. They lived thirty days, nine days, and fifty-four days, respectively. In every instance the tissue became encrusted with oxamid deposit, and in Experiment 90 a concretion developed which entirely filled the renal pelvis and measured 0.5 by 1 cm. This concrement lay in a pool of pus from which a gram-positive staphylococcus was demonstrated on culture. The rabbits that lived for nine and thirty days gave negative cultures from the kidneys and urine. Hence it may be concluded that the presence of infection in Experiment 90, in which the animal lived fifty-four days, was due to secondary invasion of bacteria to the area of lowered resistance produced by the presence of the foreign body (Fig 15).

#### SUMMARY OF CONCLUSIONS CONCERNING THE FORMATION OF OXAMID CALCULI AS DEDUCED FROM SERIES 5 AND 6

1 Oxamid fed to animals is specifically precipitated from the urine by a normal colloidal mechanism in such a way that the unit crystals tend to fuse, probably in loose chemicophysical union with certain of the colloids.

2 The concretions formed as the result of this fusion have the general physical features of calculi seen clinically.

3 The process is sterile at least at the beginning.

4 A considerable amount of the material thus deposited is passed on with the urine, but an occasional fragment is retained in the calices or at points where the adhesive force between the minute fragment and the epithelium of the urinary tract is great enough to resist the force of the urinary stream.

5 Duplication of surfaces, diverticula, stasis, hydronephrosis, of such a degree as not to upset markedly the pressure equilibrium of urinary secretion, and organic nuclei greatly enhance the chances of retention of the fusing crystals and in this manner foster the formation of larger stones

6 Oxamid concretions while sterile at the outset probably act after a time as foreign bodies and invite bacterial invasion which may in turn cause an increase in concrement growth

SERIES 7 THE INTRODUCTION OF INFLAMMATORY EXUDATES INTO THE URINARY STREAM BY MEANS OF EXPERIMENTAL RENAL INFECTION THE INFLUENCE OF SUCH EXUDATES UPON THE DEPOSITION OF CALCIUM OXALATE AND THE PRODUCTION OF SMALL CONCRETIONS BY SUCH METHODS

After the mechanism of the formation of oxamid stones had been established, at least in principle, it was felt that an analogous process must take place in calculi seen clinically in human beings. In the urine of normal animals when the saturation limit for oxamid is reached (0.02 to 0.03 gm. for each 100 cc.),<sup>9</sup> there is precipitation of fusing crystals. This is not the case with oxalates, urates, and so forth, which, their saturation limit having been reached, are precipitated as isolated, unfused units.

What if abnormal colloidal material such as that contained in pus or inflammatory exudates is introduced into the urinary stream? Will the normal precipitating mechanism of the urine be disturbed? Under such condition what will be the result of the concentration of oxalates in the urine in Series 2? Inflammatory exudates contain amino-acids, albumin, nucleoprotein, albumoses, proteoses, peptones, enzymes, lecithin, fat, cholesterol, and purin bodies, held for the most part in colloidal solution. Most of these materials are present in normal urine in traces or not at all.

*Experiments 35 to 49*—Minute doses of colon bacilli (twenty-four hour and old cultures) were injected directly into the left kidney of rabbits by means of needle puncture, the kidney was located by palpation under anesthesia. Four-tenths gram of sodium oxalate was fed daily to thirteen rabbits. In Experiment 49 0.5 cc. of butyl oxalate was given daily. The fourteen rabbits developed suppurative pyelone-

9 In Experiments 67 and 68 the oxamid output was determined by hydrolysis to oxalic acid and quantitatively by means of a modification of the Autenreth-Barth technique for this material. The twenty-four hour specimens of urine contained from 0.02 to 0.03 gm. of oxamid (as oxalic acid) for each 100 cc. after the sediment had been removed by filtration. (Brugsch, T., and Schittenhelm, A. *Technik der speziellen klinischen Untersuchungsmethoden*. Berlin: Urban und Schwarzenberg, 1914, pp. 783-784.)

phritis which caused their deaths after a period varying from several days to two weeks. Three animals of the series (Experiments 35, 36 and 44) had atypical crystalline deposit in the calices, the largest deposit was about 0.5 mm in diameter. Crystalline deposit was not found in the kidneys of the remaining animals. The crystalline morphology of the calcium oxalate excreted under such conditions has not yet been determined. In Experiment 49, in which butyl oxalate was fed after the injection of a stool culture from the rabbit into its own left kidney, a number of atypical crystalline particles were seen in the urine. However, no concretions were found.

SERIES 8 THE PRODUCTION OF A MINUTE CONCREMENT  
BY MEANS OF TRAUMA AND INFECTION

Cushing,<sup>10</sup> in 1899, traumatized the gallbladder of a dog and soon thereafter introduced into a vein an attenuated culture of typhoid bacilli. An acute cholecystitis ensued and minute concretions were found in the gallbladder. This suggested a similar experiment on the kidneys.

*Experiment 50*—A left nephrotomy was made on a rabbit through a flank incision, under anesthesia and aseptic conditions. The renal pelvis was thoroughly traumatized by pinching with mosquito forceps, the kidney and wound were then closed. One cubic centimeter of a twenty-four hour culture of colon bacilli, which had been obtained from a calculus removed clinically, was injected into the vein of the ear. The rabbit died after eight days. Acute pyelonephritis and several small doubly refractile bodies, about 0.5 mm in diameter, were found in the calices at necropsy. The crystalline bodies were not associated with the line of suture. Repeated efforts to duplicate this result (Experiments 51 to 54) have proved futile. Whether the strain of bacteria which was associated with the concrement in Experiment 50 was that of a specific stone-producing bacillus, which lost its power in subculture, or whether the concretions were encrustations on necrotic tissue is an open question. A conclusion cannot be drawn from a single experiment which cannot be repeated.

CONCLUSIONS FROM SERIES 7 AND 8

Inflammatory exudates are associated possibly experimentally with a change in morphology of calcium oxalate crystals when deposited in

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<sup>10</sup> Cushing, Harvey. Typhoidal Cholecystitis and Cholelithiasis. Discussion of a Possible Agglutinative Reaction of the Bile and Its Relations to Stone Formation, *Bull. Johns Hopkins Hosp.* 9: 91-95, 1898, Observations upon the Origin of Gallbladder Infections and upon the Experimental Formation of Gallstones, *ibid.* 10: 166-168, 1899.

urines containing such exudates. Several small concretions made up of atypical fused crystals have been observed under such conditions.

#### CONCLUSIONS FROM THE ENTIRE EXPERIMENTAL STUDY

1 The difficulty with which calcium salts, oxalates, urates, and other normal crystalline deposits of the urine are increased to any appreciable degree by various methods of administration has been pointed out. The only marked increase in visible crystals has been attained by feeding oxamid, a material foreign to the urine of animals. From this it would seem that an exogenous or dietary increase in crystalline materials would not produce a corresponding pathologic increase of these materials in the urine. On this basis, oxalurias, phosphaturias, xanthinurias, cystinurias, and excessive uric acid output must be more of endogenous than of exogenous origin. Some defect of metabolism by which the colloidal content or hydrogen ion concentration of the urine is altered, rather than a defect of diet, is at work.

2 Of the four methods by which artificial concretions have been obtained, only the feeding with oxamid gave consistent results. There were suggestive features in connection with the other experiments which pointed to the working of some abnormal precipitation mechanism.

3 Oxamid, a crystalloid foreign to the urinary tract, on being excreted, finds no mechanism present to keep its crystals separate as morphologic entities. Rather it is precipitated with colloidal material of normal urine in such a way that fusion of crystals and concrement formation ensue.

4 Mechanical factors are effective, at least, in the case of oxamid, in promoting retention of crystals and growth of the stones, but they are not essential to the process.

#### SUMMARY

The work with regard to establishing the cause of calculus formation has only begun, and all one can hope to do is to arouse interest in a field of research which has received little attention for a number of years. However, the preceding studies have suggested several ideas which seem consistent with clinical and experimental facts.

*A Protective Mechanism Against Stone Formation*—Why are not stones formed in the urinary tract of all animals? The human being puts out, on an average, from 2 to 4 gm daily of material which yields precipitates practically insoluble in water. What prevents the water-insoluble materials from being precipitated and becoming encrusted on the walls of the urinary tract, or clogging it with concretions, just as pipes carrying lime water become covered with calcium carbonate scale? Obviously, nature has provided a defensive mechanism against such deposits in animal excretory organs, more particularly in the urinary tract.



1 *Natural Defense Against Excessive Concentration of Urinary Crystalloids*—Clinically and experimentally, it has been found that overconcentration of normal urinary crystalloids by dietary means is practically unknown. It is probably impossible. Nature has provided this defense against excessive crystalline deposition in the urinary tract as our first line of defense against stone production.

2 *Protective Colloids*—The ability of the urine to hold in solution a moderate quantity of material which is practically insoluble in water constitutes a second line of defense against calculus formation. This property of the urine is related to the hydrogen ion concentration and to the presence of protective colloids, as emphasized by Lichtwitz.<sup>11</sup>

3 *Precipitation of Crystals as Isolated Units*—The third factor of stone prevention lies in the ability of the urine, when it becomes supersaturated, to deposit its crystalline material in isolated, morphologically complete, crystal units which have no tendency to fuse.

4 *The Form and Activity of the Urinary Tract*—The fourth natural protection against the formation of stone may be found in the anatomy of the urinary tract. The calices lead to the pelvis with open, unobstructed orifices, the pelvis is funnel-shaped and actively contractile, as are also the ureter and bladder, all tending to push any foreign body forward with the urine. It is remarkable that so early a writer as Aretaeus<sup>12</sup> was familiar with this natural defense, for he says, "Nature, therefore, did well in forming the cavity of the kidneys oblong, and of equal size with the ureters, and even a little larger so that if a stone formed above, it might have ready passage to the bladder." So if, in spite of our first three mechanisms, namely, the metabolic protection against excessive concentration of urinary crystalloids, the protective colloids, and isolation of crystals, we should have a formation of small deposits of fused crystals, then this fourth active extruding factor would come into play. This idea is borne out by the frequent passage of small multiple stones and sand which is often seen in patients.

The biliary tract, in this connection, is not such an open system. The inactivity of its contractions, its sinuses of Luschka, valves of Heister, tortuous cystic duct, ampulla of Vater, and sphincter of Oddi, all offer obstruction to the extrusion of crystalline deposits. This may be a significant factor in explaining the greater frequency of gallstones than of urinary concretions.

11 Lichtwitz, L. Untersuchungen ueber Kolloide im Urin II. Ueber Beziehungen der Kolloide zur Loeslichkeit der Harnsaure und harnsauren Salze, Ztschr. f. physiol. Chem. **64** 144-157, 1910; Lichtwitz, L., and Rosenbach, O. Untersuchungen ueber Kolloide im Urin I. Ueber Kolloide im normalen menschlichen Urin, *ibid.* **61** 112-118, 1909.

12 Adams, F. The Extant Works of Aretaeus, the Cappadocian, London: Sydenham Soc., 1856, pp. 340-343.

Except in the case of xanthin and cystin calculi, no metabolic error has ever been demonstrated to be associated consistently with lithiasis. In gout, oxaluria, and phosphaturia, our natural defenses against stone formation are actively at work. As a result, stone is the exception in such cases and not the rule.

Cystinuria and xanthuria present unusual crystals in the urinary stream. Their similarity to our artificial oxamurias in this respect is noteworthy. Here again it may be conceived that the urinary colloids and precipitating mechanism are inadequate properly to handle cystin and xanthin, and a tendency to the formation of stone is the result.

*Calculi Due to Abnormal Colloidal Matter in Urine*—There seems to be no other reasonable explanation than that the formation of calculi is due to a disturbance of the normal colloidal mechanism of the urine, either in holding water-insoluble materials in solution or in precipitating crystals as isolated entities. This disturbance may be due to quantitative or qualitative change in the colloids normally present, or to the entrance of abnormal colloids to the urine, either from the blood stream or as products of local disease in the kidney. The latter origin seems most likely.

*Specific Exudates from Specific Infection, the Source of Stone-Forming Colloids*—The fact that pus and exudates of bacterial origin, aside from nephritis, are the most common known sources of pathologic colloidal material in the urine makes it seem likely that these constitute the factors by which the normal urinary precipitation mechanism is most frequently upset.

Inflammatory exudates contain albumin, nucleoprotein, lecithin, fatty acids, and other colloids which are foreign to the urinary tract. In consequence of the presence of these pathologic colloids, crystalline material is deposited abnormally. The crystalline material is combined with the organic colloidal material, and when deposited assumes atypical shape and physical structure. Furthermore, these crystals no longer remain isolated but tend to fuse. These fused bodies are for the most part passed on with the urine, but some are retained. Other crystals soon become deposited on the retained mass, and thus a concrement arises.

One point should be emphasized. Not every abnormal colloid introduced into the urinary stream will be associated with atypical crystalline deposits or stone. Were this the case, nephritis and pyelitis would consistently be associated with stone. This leads us again to but one conclusion. The stone-forming colloid must be specific, and if due to bacteria the bacteria which produce it must be specific.

Thus we go back to the doctrine of Meckel von Hemsbach who, in 1856, conceived of a "stone-forming catarrh." The demonstration of the elective action of bacteria in different diseases and especially in those

of the kidney, the experimental production of gallstones, of alkaline phosphatic cystitis, and within the last few months, of renal concretions by the methods of Rosenow,<sup>13</sup> almost add the final word to this idea of concrement formation

*Possibility That Calculi Are Occasionally Due to Noninfectious Colloidal Changes*—In spite of the abundant evidence for a bacterial etiology of stone, it is possible that some calculi are not due to infection. Urinary crystalloids may be excreted in such excessive amounts that the normal urinary colloids cannot handle the burden and keep the individual crystals isolated.

On the other hand, qualitative or quantitative changes in the urinary colloids may sometimes be brought about by causes other than bacterial infection. Such changes might rarely lead to the deposition of fusing crystals and consequent formation of stone even though the urinary crystalloid excretion remains within normal limits.

*The Rôle of the Mechanical Factors*—In stasis, surface duplication, organic nuclei, and diverticula are seen conditions which do not cause stone but which, if the cause of stone is present, will greatly favor its growth. This has been demonstrated to be the rôle of mechanical factors in the case of oxamid, and all clinical evidence supports such a view for calculi in human beings.

*Clinical Application*—The clinical application of this conception of calculus formation strengthens the experimental data. The stone-forming kidney becomes easily understood. The infected kidney pours abnormal colloids into the urine. These cause constant precipitation of crystalloids and fusion of the crystals precipitated. It may be seen readily why the removal of such a kidney is so seldom attended by recurrence of stone, why the recurrence of stone in the infected bladder is so frequent, why bad teeth and tonsillitis, conditions of lowered nutrition, states of inactivity, alcohol or carbohydrate fermentation in the stomach, and other conditions of lowered bodily resistance are accused by various authors of playing a part in the process of lithiasis.

Difficulty is encountered when an attempt is made to explain the high incidence of stone in persons living in India and China, the association of uric acid gravel and uric acid infarcts in children, the alleged association of stone with previous injuries to the vertebral column and spinal cord, and other similar more obscure features of lithiasis. A tentative explanation is the fact that certain physical, climatic, geographic or physiologic differences at times lower the resistance to stone-forming infections.

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13 Rosenow, E. C., and Meisser, J. G. Nephritis and Urinary Calculi After Production of Chronic Foci of Infection. Preliminary Report, J. A. M. A. 78: 266-267 (Jan. 28), 1922.

Attention should be called also to the occasional instances of spontaneous disintegration of calculi. Englisch<sup>14</sup> collected more than 100 such cases which he considered authentic and a number of others which were questionable. This phenomenon has been explained as due to a resolution of the organic framework, or matrix, of the stone. Rosenbach showed that the kidney stones of man placed in the renal pelvis of animals diminished in size. This suggests that solution of the organic matrix may take place under unusual circumstances.

#### CONCLUSIONS

The biochemist and physiochemist must lead in the study of the complexities of action of urinary solvents and the states of materials held in solution. As yet, knowledge of the urinary colloids and pigments is very slight, in a true physiochemical sense. In trying to deal with problems of this kind one immediately finds the borderline of scientific knowledge.

On the clinical side, an endeavor must be made to learn what type of bacteria is associated with the process, and whether or not there are specific strains for each chemical in the calculus-forming group. It must be decided why one patient has an oxalate and another a urate or phosphate calculus, why one has a single small stone for years, while another passes many of such size, and why still another presents himself with both kidneys filled with branching stones and without a history of ever having passed sand.

These are the broader aspects of the problem of urinary lithiasis. It is fair to assume, however, that a proper cooperation of biochemists, bacteriologists, and urologists will clear up these points ultimately and bring the problem to a satisfactory solution.

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<sup>14</sup> Englisch, J. E. Ueber spontane Zertrümmerung der Harsteine in der Blase, *Arch. f. klin. Chir.* **76**: 961-1056, 1905.

# THE NATURE OF CRANIAL HYPEROSTOSIS OVERLYING ENDOTHELIOMA OF THE MENINGES

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CHICAGO

Local changes in the skull overlying meningeal endotheliomas occur sufficiently often to make their recognition a point of considerable value in distinguishing between endotheliomas and other brain tumors. The changes are of two types, localized bony thickening and local erosion.

## LOCALIZED BONY THICKENING

Much the commonest change is localized bony thickening. Cushing<sup>1</sup> found that it was present in some degree in at least 25 per cent of his eighty cases of meningeal endothelioma. Inasmuch as the proportion of endotheliomas to gliomas is between one to two and one to four (seventy-five meningeal tumors to 142 gliomas in Tooth's<sup>2</sup> series, and eighty endotheliomas to 312 gliomas in Cushing's series), the detection of the hyperostosis would be of value in distinguishing between these two main groups of tumors in one out of every eight to sixteen cases.

Virchow,<sup>3</sup> in 1864, stated that he had several times noticed thickening of the skull overlying endothelioma of the dura. Féré and Arnould,<sup>4</sup> in 1887, reported a case, with symptoms of brain tumor of six years' duration, and a bony thickening of the frontal region for eight months. At necropsy the hyperostosis was found to lie over an egg-sized "angiolithic sarcoma," attached to the inner surface of the dura and projecting into the frontal lobe.

The usual interpretation has been that the growth of the underlying tumor stimulated the overlying bone, leading to nontumorous new bone formation, without recognition of the fact that the bone becomes infiltrated by tumor. This has been the explanation given particularly by German writers, as Krause<sup>5</sup> and Kuttner<sup>6</sup>. Early

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1 Cushing, Harvey. The Cranial Hyperostoses Produced by Meningeal Endotheliomas, *Arch Neurol & Psychiat* 8 139 (Aug) 1922

2 Tooth, H. H. Some Observations on the Growth and Survival Period of Intracranial Tumours Based on the Records of Five Hundred Cases, with Special Reference to the Pathology of the Gliomata, *Bram* 35 61 (Nov) 1912

3 Virchow. Die krankhaften Geschwuelste 2 115, 1864-1865

4 Fere, C., and Arnould, E. *Compt rend Soc de biol* 4 220, 1887

5 Krause, F. Die allgemeine Chirurgie der Gehirnkrankheiten, Stuttgart, 1914

6 Kuttner, H. Handbuch der praktischen Chirurgie, Stuttgart, Enke 1 410, 1921

reports of microscopic examination of the involved bone are rare. Brissaud and Lereboullet,<sup>7</sup> in 1903, reported two cases which they considered hemicraniosis, i. e., a growth disturbance, associated with angiolithic sarcoma of the dura, but no microscopic examination was made of the bone. They assumed that the dura mater during youth, in its osteogenic capacity produced the progressive hyperostosis of the skull, when the growth period was finished, its activity was turned in another direction and led to the formation of the intrameningeal tumor. Parhon and Nadjede<sup>8</sup> in 1905 reported a similar case and gave an abstract of one by Parhon and Goldstein. They considered the bony thickening to be of a tumorous nature, but they gave no details as to its microscopic appearance. Babes, in a discussion as to the relationship between the two tumors considered them to be of a different nature. He thought that the bony tumor was primary and, by irritation of the meninges had led to the formation of the intradural psammoma.

Barling and Leith's<sup>9</sup> case, in 1906 was the first published in which it was shown by histologic examination that cells of the same nature as those contained in the intracranial tumor were present throughout the hyperostosis. They considered that the tumor was primary in the meninges, with secondary invasion of the bone by direct extension. No mention is made of the character of the new bone, and it is not stated whether it is believed to come from the tumor or from the invaded skull.

Spiller,<sup>10</sup> in 1907, reported two cases of tumor of the dura mater, with thickening of the overlying bone. He was the first to point out the fact that any pronounced local thickening of the skull is likely to be associated with a tumor involving the underlying meninges. No pathologic report was given of the thickened bone, and it was not stated whether he considered the thickening a hemicraniosis as it was considered by Brissaud and Lereboullet, or due to tumor invasion, as found by Barling and Leith, whose case he cited. From a review of the literature, it appears that the thickened skull has many times been mistaken for the primary tumor and considered as sarcoma, osteoma or exostosis. I have recently seen two cases in which the disease had been considered sarcoma of the skull. In such cases, the intradural lesion has been either overlooked or considered secondary, from direct extension through the dura.

7 Brissaud and Lereboullet, P. *Rev. neurol.* **11** 539 (June) 1903.

8 Parhon, C., and Nadjede, G. *Rev. neurol.* **13** 1017 (Nov.) 1905.

9 Barling, H. G., and Leith, R. F. C. *Lancet* **84** 282 (Aug. 6) 1906.

10 Spiller, W. G. *Hemicraniosis and Cure of Brain Tumors by Operation*, J. A. M. A. **49** 2059 (Dec. 21) 1907.

Cushing's recent report of the first extensive series studied by a single observer contains much general information on the subject, especially as to the frequency of occurrence and the localization of the hyperostoses and the types of intradural lesions producing them. Tumors of the frontal and temporal regions, and particularly those whose origin is near the falx, were found to produce bony thickening most frequently. The primary intradural tumor was of two types, either spherical and embedded in the brain substance, with a variable extent of attachment to the dura, or endothelioma en plaque, with a broad attachment to the dura, and producing only slight indentation of the brain surface. The latter was much more inclined to produce hyperostosis than the former, and the hyperostosis was likely to be larger, the exact reasons for which were not clear. That the degree of hyperostosis was not definitely related to the extent of dural attachment was shown by cases in which rounded tumors with small dural attachments caused marked bony thickening. Cushing found endotheliomatous invasion of the thickened bone in all cases in which it was examined, and he considered the thickening to be due to the stimulating effect of the invading tumor, although he thought it possible that the ossification might be of the tumor and in some way connected with the osteogenetic power of the dura.

#### REPORT OF CASES

As yet there have been few detailed studies published of both gross and microscopic features of the thickened bone and of its relation to the underlying dura. The two cases reported herewith have afforded opportunity for such study, and throw some light upon these points.

CASE 1—R. M. man, aged 40, entered the Presbyterian Hospital in March, 1915, on the service of Dr. Bassoe, giving a history of headaches during the last two years, which had gradually increased in severity and frequency. For six weeks, there had been failing vision and attacks of vomiting. The examination showed greatly reduced vision and bilateral choked disk. It was otherwise negative, there being no focal symptoms of brain tumor. A roentgenogram was taken, but the findings were not recorded, and the plate was subsequently lost. A subtemporal decompression was performed by Dr. Bevan, and ten months later, because of recurrence of symptoms of intracranial pressure, the cerebellar region was explored, but no tumor was found. Death occurred eleven months after admission.

At necropsy, after reflection of the scalp, a diffuse hyperostosis was noted in the right occipital region. On removal of the skullcap, a crater-like depression was found in the right occipital lobe, produced by an internal bony thickening similar to and opposite that on the outside and markedly adherent to the dura. A large spherical tumor was deeply embedded in the underlying occipital lobe and adherent to the overlying dura at the tip of the depression (Fig 1).

Bassoe<sup>11</sup> has published a pathologic report of the tumor. It was an endothelioma with numerous whorls, but with complete absence of either calcification or ossification. The dura in the region of the tumor and hyperostosis was well preserved, and its vascular markings could be made out. At the pit of the crater into which the hyperostosis fitted, there was a small perforation. The tumor was spread out laterally and anteriorly for several centimeters in a thin layer between the dura and brain substance. Microscopic



Fig 1 (Case 1)—Coronal section through right occipital lobe and overlying thickened skull, dura removed from lateral portion of depression and lateral cortex (a) tumor mass dipping into brain, (b) thin layer of tumor spread over lateral cortex of lobe, (c) outline of old calvarium, and (d) tumor filling superior longitudinal sinus

examination of the dura, excised near the apex of the depression, showed extensive tumor infiltration with marked dilatation of some of its vascular spaces and tumor invasion of others. Sections of the dura overlying the

11 Bassoe, Peter. Two Cases of Tumor of the Occipital Lobe, Tr. Chicago Path Soc., 1917, p. 118





Fig 2 (Case 1) —Roentgenogram of section, showing spongy character of hyperostosis and of invaded calvarium as compared with the denser uninvolved portion (a)

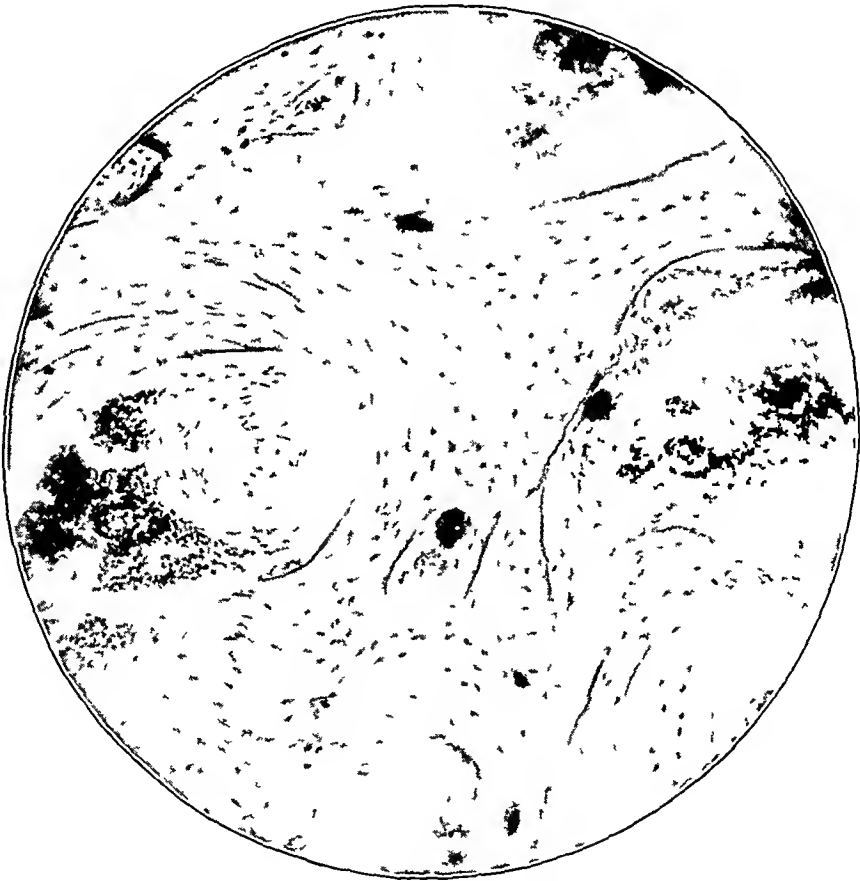


Fig 3 (Case 1) —Endothelioma infiltrating calvarium

thin layer of the tumor spread out between it and the cerebral cortex showed very little invasion by tumor cells

Section through the middle of the overlying thickened bone revealed clearly the outline of the old calvarium. The zone of hyperostosis averaged 7 cm in diameter and gradually tapered off toward the periphery. The thickening was slightly greater on the outside than on the inside. The skull measured 26 cm in its thickest portion. The new bone was, in general, spongy, but in places it had a slight tendency to radiate from the outer and inner tables. The calvarium was definitely more spongy in the region of the hyperostosis than in its uninvolved portion. The inner surface of the hyperostosis was quite rough and showed many grooves and canals, some of which were vascular markings. The outer surface was covered by smooth pericranium. A roentgenogram of an excised narrow strip revealed the spongy character of the hyperostosis and the reduced density of the outer and inner tables, as compared with the uninvolved skull at one end of the section (Fig 2)



Fig 4 (Case 2) —Appearance of patient on examination

Microscopic examination showed endothelioma of the same character as the intradural tumor, infiltrating almost uniformly the entire hyperostosis and the portion of the skull from which it sprang (Fig 3). The cancellous spaces were largely filled with tumor and blood vessels, red marrow being extremely scanty. New bone was being formed about the surface of the external layer, and its nontumorous nature could be definitely made out. In the regions of most marked growth, tumor cells were largely absent in the vicinity of the newly formed trabeculae, and bone formation from tumor cells was nowhere to be seen. Fibrous bands dipped into the substance of the exostosis at irregular intervals, especially about the pericranial surface, dividing it into radiating columns. Along the endosteal surface, tumor was especially abundant and extended into the slight remnants of dura which were adherent to the hyperostosis in a few places.

CASE 2—A H, man, aged 31, was admitted, Aug 15, 1922, to U S Veterans' Bureau Hospital No 76. During the previous two years, a hard, bony, oval swelling had gradually developed in the left frontoparietal region. There were

no other symptoms. Examination revealed a large, oval, bony, hard, painless swelling in the left frontoparietal region, extending forward almost to the orbit, backward as far as the plane of the posterior part of the auricle, and mesially just beyond the midline of the skull (Fig 4). There were no other positive findings. The nervous system and eye-grounds were negative. A roentgenogram showed a shadow in the region of the tumor, gradually increasing in density toward its central portion. The new bone, extending beyond the outline of the outer table, cast a faint, but definitely radiating, shadow (Fig 5). A probable diagnosis was made of meningeal endothelioma, with overlying hyperostosis.

Operation was performed in two stages, ten days apart. A large flap was turned forward and to the left, and five trephined openings were made about



Fig 5 (Case 2) —Roentgenographic appearance of head

the periphery of the tumor. All except one of the intervening bridges were cut, and the wound was closed. Ten days later, the wound was reopened, the remaining bridge cut and the thickened skull removed. It was markedly adherent by its inner surface, and, in one place, the outer layer of dura was removed with it. The exposed dura was then opened, and a broad, flat tumor was found attached to its inner surface. The involved dura was excised at a distance of about 1 cm from the margin of the tumor, except near the superior longitudinal sinus, where the tumor extended to the margin of the falx and small fragments on its external surface were left behind. These were curetted off as well as possible. Three large cerebral veins extending from the cortex in the Rolandic region to the involved dura were ligated. The wound was closed without repairing the cranial defect. Right hemiplegia and

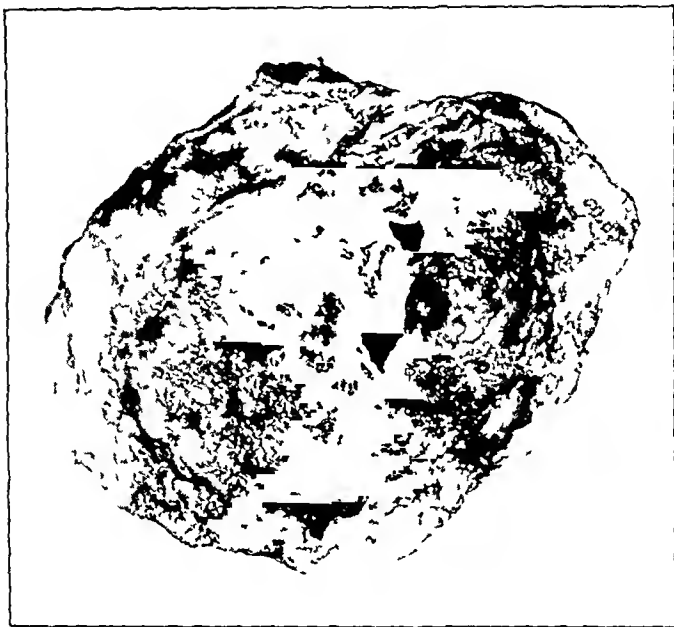


Fig 6 (Case 2) —Inner surface of excised dura, showing attached flat tumor



Fig 7 (Case 2) —Section of tumor

motor aphasia followed the operation. Three months later, both the hemiplegia and the speech disturbance were rapidly improving.

*Pathologic Report*—The excised dura presented on its inner surface, a flat, oval tumor, 8 cm long, 5 cm wide and 1.5 cm thick, at its central portion (Fig 6). The tumor was grayish red, soft and friable. It tapered off gradually at the periphery. The outer surface of the dura, which was firmly adherent to the overlying bone, had a ragged appearance and was grayish red in places from tumor infiltration. Microscopic examination showed the tumor to be composed very largely of endothelial cells which had only a slight tendency to arrangement in whorls. Evidences of cell division were

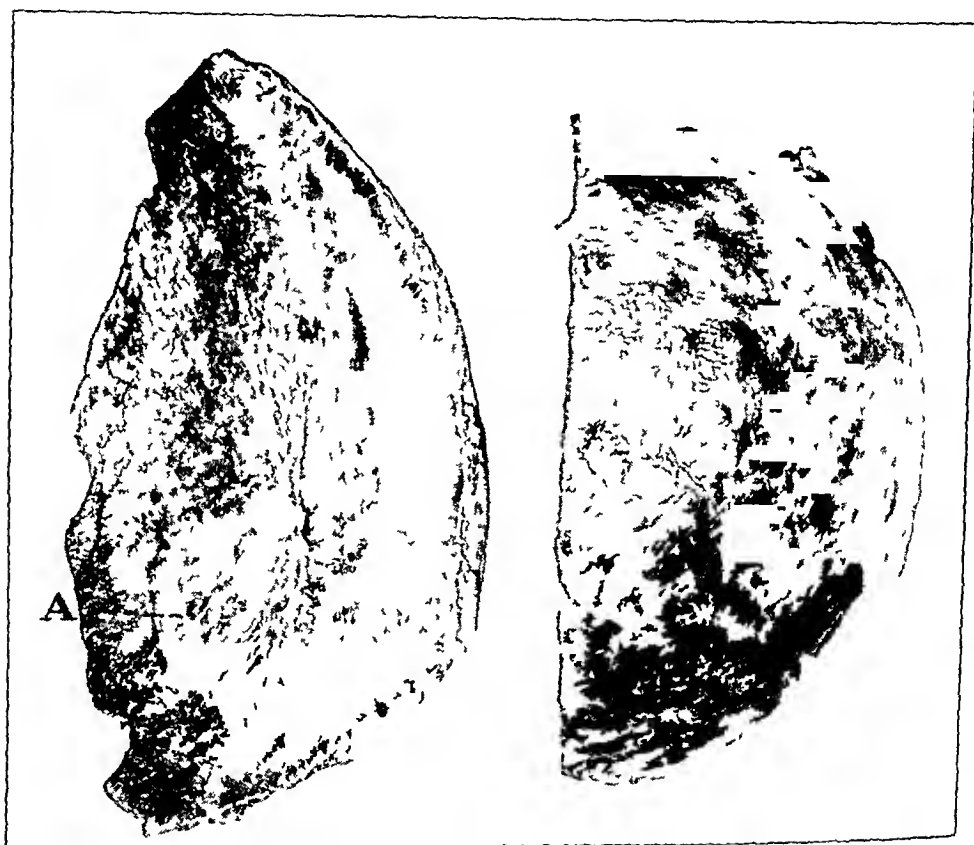


Fig 8 (Case 2) —Excised hyperostosis sawn in two, showing external, cut and internal surfaces with attached fragment of dura (a)

not seen. There was little fibrous stroma, and blood vessels were numerous. There was no evidence of hyaline degeneration or calcification (Fig 7). Sections through its attachment showed the dura extensively infiltrated with tumor, but in no place had the dural membrane been completely destroyed and replaced by tumor.

The excised portion of the skull (Fig 8) showed extensive oval bony thickening, which was more marked on the outside than on the inside. The inner surface was rough and bare, except in its lateral portion, where there was still attached a dollar-sized piece of the outer layers of dura, extensively infiltrated with tumor. The outer surface was smooth and covered by thickened pericranium with portions of attached temporal muscle. A cross

section showed the outline of the old calvarium, with a layer of new bone radiating from either surface. The maximum thickness of the skull was 4 cm, the external layer measured 2 cm, and the internal layer, 1.2 cm. The density of the outer layer was quite uniform, but that of the inner layer was more variable. In its lateral portion, which was covered by a dural fragment, there was only a small amount of ossification, and numerous radiating fibrous bands originating from bone attached the dura to the inner table. Calvarium from which the hyperostosis sprang was grayish red, and the tables were slightly porous, as compared with uninvolved portions at the periphery. A section, 0.5 cm thick, was excised for further study. A roentgenogram of it (Fig 9) showed the arrangement of the old and new bone in detail. The inner and outer tables were slightly more spongy than normal. The new bone, both internally and externally, radiated from the surface of the old bone. The rays were coarser and more uneven on the inside than on the outside. The inner layer showed plainly that ossification had proceeded from the



Fig 9 (Case 2)—Roentgenogram of excised strip, showing hyperostosis radiating from the inner and outer tables and the reduced density of invaded calvarium

inner table toward the dura and not in the opposite direction, as should be the case if the new bone were formed from the tumor. Sections including the entire thickness of the skull were cut in four places for microscopic examination. They showed a variable amount of tumor infiltration of the calvarium and of the new bone springing from it. The tumor was of the same character as the primary growth. The inner layer of new bone was extensively infiltrated (Fig 10), but there were numerous areas, especially in its denser portions, which contained little tumor. The inner and outer tables were more porous than normal, and there was considerable tumorous infiltration of them as well as of the diploe. The external hyperostosis contained the least amount of tumor. Its deeper and peripheral portions were considerably infiltrated, but the superficial bone in the thicker portions was almost entirely free from tumor (Fig 11). There were marked degenerative changes in the deeper areas, the result of circulatory disturbance produced by the first operation. Coarse bony trabeculae sprang from the tables at right angles to their surfaces, and many of them showed evidences of new bone formation at their

tips In some regions, tumor almost completely filled the cancellous intercolumnar spaces In others it was mixed with fibrous bone marrow The new bone, which was free from tumor, contained a richly cellular fibrous and hemopoietic marrow There was no question that the new bone was not tumor, for in many places along the surface where it was in the process of formation, several adjacent low power fields failed to reveal a tumor cell A section through the region of attached dura disclosed that it was extensively infiltrated with tumor Much of this ran parallel to the dural fibers, but in places tumor



Fig 10 (Case 2) —Internal hyperostosis with much tumor in the cancellous spaces

bands broke through the membrane and ran at right angles to the overlying new bone No large vascular channels were seen to pass from dura to skull, along which the tumor had spread While the hyperostosis was much more marked in this case than in Case 1, the tumor infiltration of the new bone was very much less marked and less uniform in distribution

#### COMMENT

The findings in these two cases suggest the following order of development of pathologic changes The primary tumor arises inside the dura from cells connected either with its inner lining or with the

arachnoidal villi which project into the dura, as held by M B Schmidt<sup>12</sup> and Cushing and Weed<sup>13</sup> As the tumor grows, its cells penetrate the dura and invade the overlying bone, throughout which they spread Instead of eroding the skull, the tumor exerts a stimulating influence upon it The result is the formation of a hyperostosis, which consists of two intermixed portions, namely endothelial tumor and a newly formed, nontumorous bony framework The proportions of each vary



Fig 11 (Case 2)—Section of proliferating surface of external hyperostosis showing nontumorous new bone formation and only one island (a) of tumor, (b) pericranium

in different hyperostoses and in different portions of the same hyperostosis, as shown by comparison of the findings in these two cases That the new bone does not originate from tumor cells is substantiated by a number of facts In the first place, the intrameningeal portion

12 Schmidt, M B Arch f path Anat u Physiol **170** 429, 1902

13 Cushing Harvey, and Weed, L H Studies of the Cerebrospinal Fluid and Its Pathway IX Calcareous and Osseous Deposits in the Arachnoidea Bull Johns Hopkins Hosp **26** 367 (Nov ) 1915



of the tumor does not ossify, at least to any appreciable extent. If its cells were osteogenetic, there should be ossification of the intradural as well as of the extradural portion. The arrangement of the new bone suggests that its origin is from the skull instead of from the tumor. It grows out of, and, to a variable extent, radiates from, the old bone. Microscopically, the new bone is seen to form from normal osteoblasts and not from tumor cells.

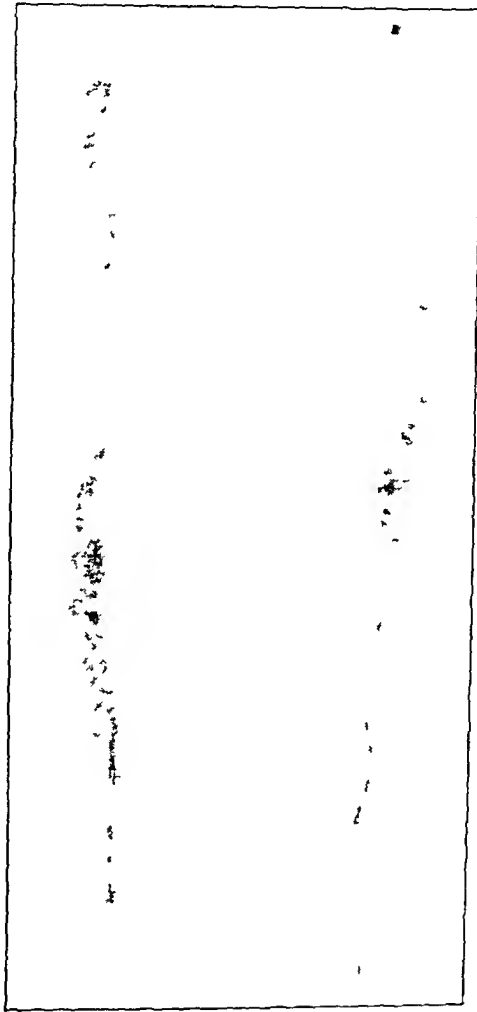


Fig. 12—Segment of femur infiltrated with osteoplastic metastases from carcinoma of prostate, new bone in the surface nodules has finely radiating arrangement.

The reasons for this invasion of the bone and for its osteoplastic response are not well understood. Endotheliomas behave as do benign tumors in their method of spread, which is always by direct invasion of surrounding tissue and never by metastasis. However, in this deeply penetrating infiltration of bone, they resemble malignant tumors. Also their tendency to invade the dura and grow for long distances in

its vascular channels is well known. In Case 1 the adjacent portion of the superior longitudinal sinus was completely filled with tumor, and the growth extended as far back in it as the torcular herophili. With regional blocking of the normal venous channels of the dura from tumor invasion, there may be a compensatory increase and dilatation of vascular connections with the overlying bone, facilitating tumor infiltration. Spread of the tumor into the bone may be favored in this way, in the absence of increased intracranial pressure which would tend to drive blood and tumor toward the periphery.

The hyperostosis is then an instance of osteoplastic invasion of bone by a mesoblastic tumor originating outside the skeleton. Invasions of bone by all other nonbony mesoblastic tumors, whether by direct extension or through the blood stream, are osteoclastic, that is, they destroy bone, and there is no new bone formation throughout their substance. Analogous changes are produced by carcinomatous invasion of bone. Usually, carcinoma metastases are osteoclastic, but, in certain instances, notably when from carcinoma of the prostate, they may stimulate new bone formation, and ossification occurs throughout the substance of the metastases. The medullary cavity of a long bone or the cancellous spaces of a short one, as a vertebra, may be completely filled with new bone formed as the result of stimulation by such metastases, and carcinomatous nodules springing from the surface of such a bone may possess an ossified stroma with slight radiations, similar to that in the hyperostosis shown in Case 2. In Figure 12 is reproduced a roentgenogram of a postmortem specimen of a femur, with ossified metastases both in the medullary canal and along the surface of the cortex, secondary to carcinoma of the prostate. The new bone is, of course, formed from the old and not from carcinoma cells, and fine radiations are to be seen in the peripheral portions. These were best seen on microscopic examination. Von Recklinghausen<sup>14</sup> explained the new bone formation in ossifying carcinoma metastases in the following way. The tumor growth lies almost entirely within the veins and obstructs them, producing marked passive hyperemia of the region. This stimulates the new bone formation. Axhausen<sup>15</sup> and Schmorl<sup>16</sup> believe that the new bone forms as a result of stimulation by chemical substances liberated by the tumor cells. One type of tumor cell stimulates stroma formation, while another does not, and, when the tumor growth is within a bone, the stroma arises from it and ossifies. There is uncertainty as to the relationship between the amount of fibrous stroma contained within the intradural endothelioma

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14 Von Recklinghausen, F. D. *Festschr. Rudolf Virchow*, Berlin, 1891.

15 Axhausen, G. *Arch. f. path. Anat. u. Physiol.* **195**: 358, 1909.

16 Schmorl. *Verhandl. d. deutsch. path. Gesellsch.* **12**: 89, 1908.

and the amount of ossification within the tumor invading the skull. In Case 2 stroma was very small in amount in the intradural portion, and ossification of the skull invasion was very marked. While in the endotheliomatous hyperostoses the larger venous channels of the overlying dura and skull may show tumorous invasion, the smaller veins and capillaries are not uniformly engorged with tumor cells, as is the case within ossifying carcinoma metastases.

The arrangement of new bone within an ossifying bony tumor, whether the tumor is primary or secondary, seems to be dependent more on its amount and rate of formation than on the nature of the cells from which it springs. Whether it arises from tumor cells or from the old bone, it is arranged to support the tumor. If the growth of the tumor is fairly rapid or if the amount of bone formed throughout its substance is not very great, the newly formed bone is likely to radiate from the surface of the old. This is commonly seen in periosteal sarcomas in which the new bone is tumorous. If the rate of growth is slow or the tendency to ossification great, the newly formed bone is likely to have a dense, spongy arrangement. Combinations of the two are not infrequently seen, the deeper bone being dense and spongy while superficial portions show radiation.

Opposed to the theory that the endothelioma cells ossify as a result of osteogenetic powers contributed by the dura are not only the histologic findings, but also the fact that a tumor arising from the dural infoldings, which contain no osteoblastic layer, may produce hyperostosis. Heuer and Dandy<sup>17</sup> reported a tumor apparently springing from the falx, which extended to the surface in the lateral portion of the frontal lobe and produced bony thickening of the overlying skull. Calcification occurring in areas of hyaline degeneration in psammomas is, of course, in no way related to the bony thickening of the skull.

Primary tumors of the skull may resemble very closely these hyperostoses secondary to meningeal endotheliomas. This is particularly true of those lesions which begin early in life, grow slowly and are regarded either as benign tumors or as hyperostoses cranii. After many years of comparatively innocent growth, they may take on definite sarcomatous features. Such was the case in the remarkable bony growth, apparently primary in the left frontal bone, in the giant Wilkins, reported by Bassoe.<sup>18</sup> The patient began to grow abnormally rapidly at the age of 4, and by his eighteenth year he had attained the height of 8 feet 2 inches (249 cm). At the age of 8 a slight thickening of the frontal bone developed, just above the left orbit. This continued to grow slowly for twenty years, at the end of which time a large bony tumor

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17 Heuer, G. J., and Dandy, W. E. A Report of Seventy Cases of Brain Tumor, *Bull. Johns Hopkins Hosp.* **27**: 224 (Aug.) 1916.

18 Bassoe, Peter. *J. Nerv. & Ment. Dis.* **30**: 513, 1903.

mass had formed, involving most of the frontal bone, distorting the face and extending into the left temporal region. A second and apparently independent bony thickening formed at the temporoparietal junction, just above the left mastoid. Three months before death at the age of 28, the tumor began to increase rapidly in size and became painful. Vision was rapidly lost and symptoms of increased intracranial pressure appeared. At necropsy the tumor was found to lie entirely outside the dura. It had greatly encroached upon the left frontal and temporal lobes at the base of the brain. There was enormous bony thickening of the skull, which was mainly on the outer surface of the involved region. There was a large soft tumor between the dura and inner portion of the bony growth, which had nowhere penetrated the dura. Microscopic examination revealed a round-cell and spindle-cell sarcoma, ossifying in its outer portion. The dense peripheral portion contained much mature bone which bore considerable resemblance to an ordinary hyperostosis.

Since it has recently been demonstrated, especially by Ewing,<sup>19</sup> that endothelioma of bone is not uncommonly encountered, these cases should be analyzed from the standpoint of primary endothelioma of the skull, with secondary invasion of intracranial structures. This is particularly true of the cases, such as Case 2 of this series, with marked hyperostosis and small, flat, intradural tumor. Primary endothelioma of bone differs strikingly from these cases in that there is nearly always extensive bone destruction, with little or no associated new bone formation. This is true of the few instances, as those of Kocher,<sup>20</sup> Rustitzky,<sup>21</sup> Marckwald<sup>22</sup> and Ewing, in which the skull was the bone involved. I find no recorded case of extension through the dura producing a subdural mass and symptoms of brain pressure. Ewing has reported one case in which there was diffuse, spindle shaped enlargement of the ulna, with spongy ossification throughout the tumor.

#### LOCAL BONE DESTRUCTION

When a meningeal endothelioma invades the overlying skull, it may produce bony erosion with little associated new bone formation. The skull may be perforated, and the overlying scalp may be lifted up or invaded by the soft tumor. This condition is referred to in the old literature as *fungus duræ matris*. Andrews<sup>23</sup> has recently reported such localized bone destruction from an underlying meningeal tumor.

19 Ewing, James. A Review and Classification of Bone Sarcomas, *Arch Surg* **4** 485 (May) 1922.

20 Kocher. *Arch f path Anat u Physiol* **44** 311, 1868.

21 Rustitzky. *Deutsch Ztschr f Chir* **3** 162, 1873.

22 Marckwald. *Arch f path Anat u Physiol* **141** 128, 1895.

23 Andrews, E. W. *Surg Clinics of N America*, 1923, Chicago Number, to be published.

In some instances of tumor invasion of the skull, there forms first a hyperostosis, but, as growth continues, there is gradual erosion from within outward, not only of the newly formed bone, but also of the old bone, so that eventually the unossified portion of tumor may either perforate the skull or be covered by a thin layer of the remaining external bony thickening. Ossification may occur early in the external growth of tumor and then cease, after which a considerable amount of unossified tumor may accumulate on top of the hyperostosis. This combination is well illustrated by Case 3.



Fig 13 (Case 3) —Endothelioma of twelve years' duration, producing first hyperostosis, then erosion of calvarium from within outward and a layer of unossified tumor external to the hyperostosis

#### REPORT OF CASE

CASE 3—A woman aged 69, for twelve years had had an oval enlargement in the frontoparietal region, centering to the left of the midline. It had slowly increased in size until at the present time it formed a mass larger than the one in Case 2. During the last year there had been disturbances in gait and mental disturbance indicative of cerebral involvement. On palpation, the tumor had a bony feel in its deeper portions, but it was soft in its outer layer. A roentgenogram of the skull (Fig 13) showed spongy ossification in the deeper portion of the external tumor, but no evidences of new bone formation in its superficial part. There was a crater-like depression at the apex of the bony thickening. There was evidence of erosion of the entire

thickness of the skull from within outward, in the central and posterior portions. A piece of tumor was excised for microscopic examination. There was an unossified external layer, at least 1 cm thick, which had invaded the scalp. It proved to be a typical endothelioma containing little fibrous stroma.

#### COMMENT

There has been a tendency for pathologists to classify many of the meningeal tumors with the sarcomas, but, as Cushing has pointed out, they all possess sufficiently peculiar common characteristics, such as failure to make metastases, to be grouped separately and designated as meningotheliomas or meningiomas. Some tumors are composed very largely of spindle cells, as if they originated in the connective tissue element of the dura. The question arises whether the less the endothelial content of the tumor, the less the tendency to bone invasion. I have examined a flat tumor of the dura with the dimensions of that in Case 2, except that it was slightly thicker. The overlying bone was normal in appearance despite the fact that tumor lay in contact with it, and microscopic examination of the bone showed complete absence of tumor invasion. Histologically, the dural tumor was composed almost entirely of spindle cells arranged mainly in irregularly coursing bundles.

These cases illustrate well the extreme variation in effects upon the nervous system of tumors associated with hyperostoses. In the first case, there were typical general symptoms of brain tumor, and the hyperostosis was not sufficiently prominent to attract the attention of the clinician. In the second case, nervous symptoms were entirely absent, and the hyperostosis was the sole complaint. Such cases as the latter have not infrequently been diagnosed as sarcoma or osteoma of the skull and the underlying tumor overlooked. This has happened even when evidences of brain compression were present, as the internal hyperostosis was held responsible for the compression. In cases, as that of Spiller, in which only the thickened skull was excised, the continuation of brain pressure symptoms has led to a second operation, at which the primary intradural tumor was found and removed. A small endothelioma has been known to produce localized hyperostosis from the inner table without the development of either neurologic symptoms or external tumor, and the condition has been discovered only at necropsy (Virchow).

A point of practical importance in dealing with the thickened skull at operation has been emphasized by Cushing, Elsberg,<sup>24</sup> Krause, and others, namely, that it is not essential to remove all of the thickened bone. After removal of the intracranial tumor, there is usually little tendency for the hyperostosis to increase in size, and patients have been

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<sup>24</sup> Elsberg, C. A. in discussion on Cushing, Harvey. *Arch. Neurol. & Psychiat.* 8:139 (Aug.) 1922.

observed to remain well for years when considerable involved bone was left behind. This is additional proof of the benign nature of the tumors. However, the involved bone may continue to enlarge and produce pressure upon the brain or recurrence within the meninges. Frazier (personal communication) operated repeatedly on the patient in Case 2 of Spiller's report, before the fatal termination, several years later. A method of dealing with the defect left after removal of a large hyperostosis, as in Case 2 of the present report, would be to chisel away immediately the bony thickening from the inner and outer tables, boil the remaining calvarium while the intradural operation is being completed, and reinsert it before closure of the scalp.

#### SUMMARY

The hyperostosis which develops over a considerable proportion of meningeal endotheliomas results from penetration of the dura and direct invasion of the skull by the tumor. The tumor permeates the skull, rarefies slightly the inner and outer tables and stimulates new bone formation, usually from both the internal and external surfaces. Tumor cells are found in varying numbers throughout the cancellous spaces of the hyperostosis. The new bone is not tumorous in nature, and is merely ossified stroma of the invading endothelioma. Its spongy or radiating arrangement is similar to that which is seen in the ossification occurring in other types of tumor, whether primary or secondary in bone and whether the new bone itself is of tumorous or nontumorous nature.

# OSTEOMA OF THE SKULL

REPORT OF TWO CASES, ONE BEING ASSOCIATED WITH A LARGE  
INTRACRANIAL ENDOTHELIOMA

CARL W RAND, M D

LOS ANGELES

As far as I know, no comprehensive treatise on the subject of bony tumors of the skull, and their relationship to underlying endotheliomas, has yet appeared. Sporadic cases of cranial osteoma and hyperostosis, sometimes with, and sometimes without, this associated pathologic condition, have been reported, but these are frequently found under obscure titles. That local thickening of the skull may occur has long been known. It is seen in various systemic conditions, such as acromegaly, Paget's disease, oxycephaly, turriccephaly, periosteal inflammatory reactions, etc., as well as in actual tumor formations. In the latter conditions, the thickening may involve the skull alone or may be accompanied by an underlying endothelioma. On the other hand, intracranial endotheliomas probably more often occur without any hyperostosis of the overlying skull. A close relationship between these conditions is becoming more generally recognized, and the surgeon who sees a case presenting a local thickening of the skull is at once suspicious of some underlying tumor.

Spiller<sup>1</sup> in 1907 gave us one of the earliest finished reports of an endothelioma of the brain associated with thickening of the overlying skull. The patient was operated on by Frazier, who first removed an area of thickened bone and later—as the symptoms did not clear up satisfactorily—reopened the wound and removed an endothelioma in the region of Broca's area. On occasion, these growths may be of a more extensive nature. Mix<sup>2</sup> has reported a case in which the growth involved the scalp, skull and underlying brain. Cushing,<sup>3</sup> reporting on hyperostoses of the skull, found the condition to be present in twenty instances in a series of eighty endotheliomas. Of these twenty cases, eight were endotheliomas of the soft, flattened type, and twelve were of the rounded type, having a relatively small meningeal attachment and usually spoken of as enucleable. He believes that at least 25 per cent of cases of proved endotheliomas present demonstrable thickening of the overlying bone.

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1 Spiller, W G. Hemikraniosis and Cure of Brain Tumor by Operation, *J A M A* 49 2059 (Dec 21) 1907

2 Mix, C L. Endothelioma of the Dura. *M Clinics N Am* 5 1673 (May) 1922

3 Cushing, Harvey. Cranial Hyperostoses Produced by Meningeal Endotheliomas. *Arch Neurol & Psychiat* 8 139 (Aug) 1922



The pathology of these so-called endotheliomas has been studied by Mallory<sup>4</sup> from the standpoint of cell morphology. He has advanced the theory that they grow from the arachnoid villi rather than from the dural endothelium. In short, he denies the existence of a dural endothelium, stating that the under surface of this membrane is lined with fibroblasts rather than with endothelial cells. In comparing the structure of endotheliomas with a series of arachnoid villi in various stages of proliferation, he seems to show that the so-called dural endothelioma is composed of arachnoid cells and elastic fibrous tissue. He suggests the term "arachnoid fibroblastoma" as being more correct from a morphologic standpoint, and holds the opinion that these growths may invade the overlying bone and scalp but that they never really invade the brain tissue proper, because their blood supply is derived from the dura and not from the nonvascular arachnoid membrane.

The following cases are presented as being representative of types of hyperostosis of the skull, the first accompanied by an underlying endothelioma which filled, and grew from both sides of the longitudinal sinus, the second, a simple osteoma of the skull not associated with any true intracranial growth.

**CASE 1—History**—J. A. M., man, aged 31, married, an expert accountant, was referred by Dr. H. G. Brainerd of Los Angeles, Feb. 20, 1920. He had always been athletic, having played football, basket ball, etc., and, although he had been knocked out once or twice, there was no definite single history of severe skull injury at any time.

About January, 1913, his wife first noticed a small, hard, bony lump, about the size of a marble, on the crown of his head, near the juncture of the sagittal and coronal sutures. The patient was not aware of its presence, and had no symptoms of any kind. About February, 1914, following a severe cold, the patient states that the lump was again examined and found to be larger than before. In March, 1914, following exposure to the sun, he had his first convulsion at 4 a. m. About this time, he showed other symptoms, becoming nervous, irritable and somewhat unreliable in his business relations. In July, 1916, the second convulsion occurred, twenty-four days later, the third convulsion occurred, and eighteen days later, the fourth convulsion. The last convulsion was seen by a physician who pronounced it an attack of jacksonian epilepsy. Ten days later, the fifth convulsion occurred, and, Sept. 6, 1916, the patient was operated on at Prescott, Arizona, by Dr. J. B. McNally. A piece of bone was removed from the vertex, measuring  $2\frac{1}{2}$  by  $2\frac{1}{2}$  inches (6.3 by 6.3 cm.) in diameter, and  $1\frac{1}{2}$  inches (3.8 cm.) in thickness. The pathologic report of this tumor was "benign osteoma showing irregular growth of the bone." Dr. McNally writes as follows: "Examination of the skull showed an unusual, large prominence on the frontal bone, slightly to the left of the median line, extending as far back as the coronal suture. I found the bone to be enormously thickened, and, while it was peculiarly smooth on the surface, the section which I removed had projecting from its inner surface several

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<sup>4</sup> Mallory, F. B. The Type Cell of the So-Called Dural Endothelioma, J. M. Research **41** 349 (March) 1920.

little bony spicules, sharp pointed, which produced a shredding of the dura so that the dura mater was practically destroyed and the cortical surface was smeared with a wine-colored jelly-like substance, and all membranes at this point appeared to be destroyed. There was no evidence of pus infection. I cleaned out all the debris as gently and as carefully as possible, and controlled the bony oozing with sterile beeswax. I carefully inserted the little finger around the inner aspect of the skull for half an inch or more, but could not detect any roughness on the inner surface. I remember, however, that the anterior horn of the rim was unusually thick."



Fig 1 (Case 1) —Lateral view of skull, showing tremendous thickening of the calvarium at tumor site, 1920. The recurrence of bony growth, following attempted removal four years previously, may be noted.

The patient returned to work Nov 15, 1916, much improved. Jan 6, 1917, the sixth convulsion occurred. The seventh occurred on the 24th of March, 1917, following which the patient took several months' rest. The eighth convulsion occurred about August, 1917, the ninth and tenth, five days apart during the middle of September, 1917, the eleventh and twelfth in November, 1917, the thirteenth, Dec 15, 1917, and the fourteenth Feb 15, 1918. Nov 1, 1918 the patient contracted influenza, which was followed by double pneumonia. He was very ill for several weeks. In January 1919, the fifteenth



Fig 2 (Case 1)—Lateral view of bony tumor removed in 1920, weight, 105 gm

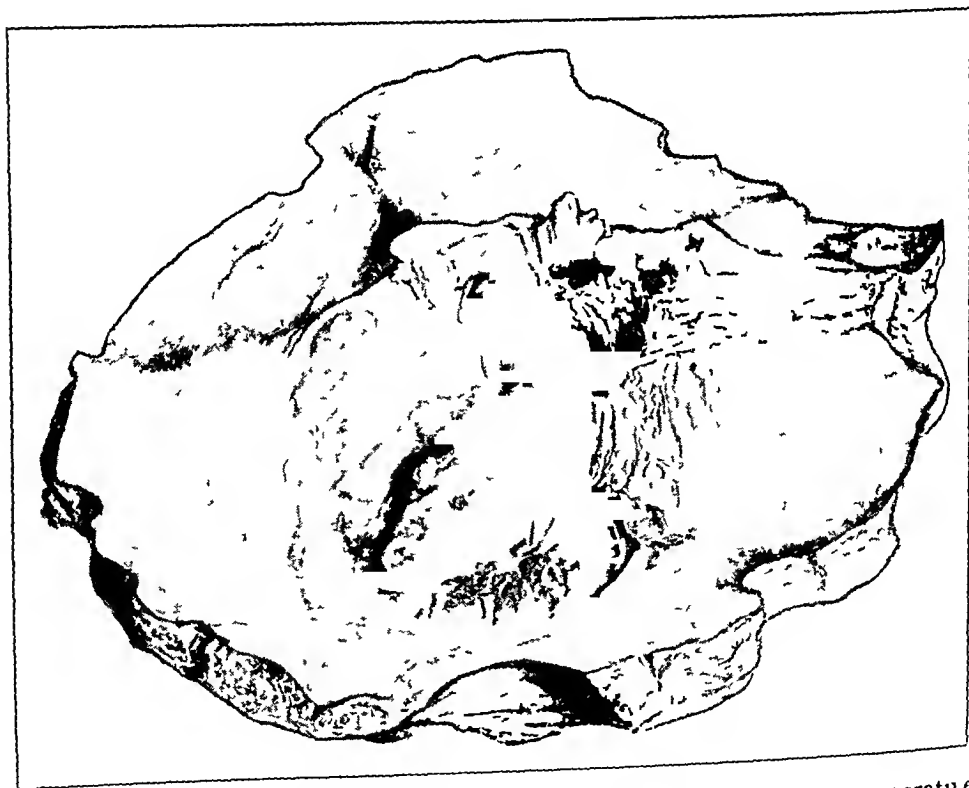


Fig 3 (Case 1)—Inferior view of bony tumor showing previous operative defect and spicular growth

convulsion occurred During this period, the patient was working, being kept on bromids About this time, he became very irritable, difficult to live with, and got into financial difficulties At one time, he left home for a week without apparent cause

*Examination*—When he came under observation, Feb 20, 1920, examination revealed a well-nourished young man, in good general physical condition, who was suffering somewhat from headache He was very nervous and irritable



Fig 4 (Case 1) —Lateral view of skull with patient in supine position The recurrence of bony growth, also inflation of right lateral ventricle with air showing the anterior horn indented and pushed down by endothelioma, may be noted The entire ventricle was not filled with air, and the fluid level of the posterior horn was sharply defined

but cooperated well on examination Neurologic findings were essentially negative except the eye grounds which showed the disk margins to be much blurred In the right fundus the disk margins could not be made out New tissue was present, and there was perivascular streaking The optic cup and lamina cribrosa were filled with new tissue No embedding of the vessels and

no measurable elevation of the disk were made out. Low grade choked disk of long standing, slightly more pronounced on the right side, was present.

A roentgenogram of the skull (Fig 1) revealed a bony elevation near the coronal and sagittal sutures, which measured about 3 inches (7.6 cm) in diameter and was elevated about  $\frac{1}{2}$  inch (1.27 cm) above the flush of the

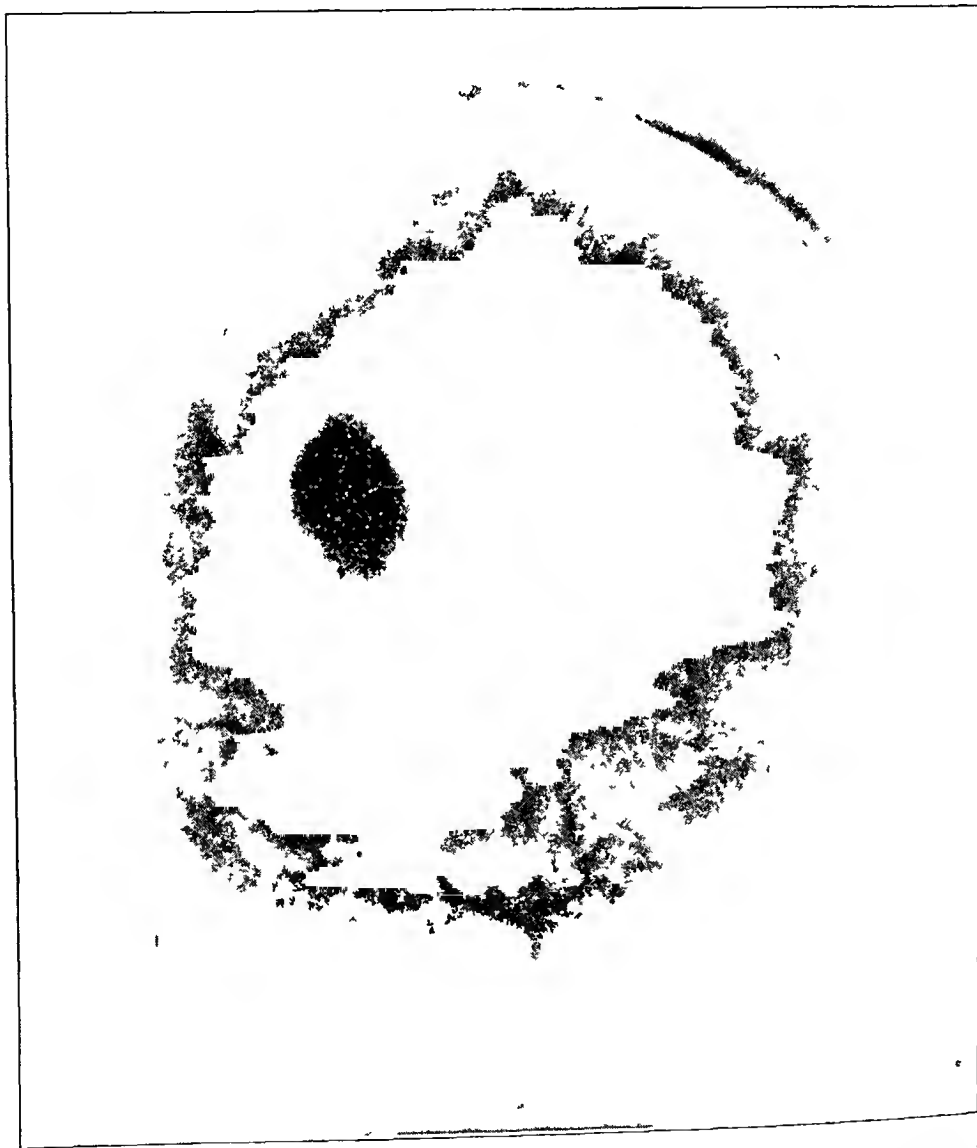


Fig 5 (Case 1) —Anteroposterior view, showing the skull defect caused by removal of the bony growth in 1920, right lateral ventricle displaced downward and outward, and left lateral ventricle entirely closed by endothelioma.

skull. There was tremendous thickening of the skull about this elevation. In fact, it appeared to be  $1\frac{1}{2}$  inches (3.8 cm), or more, in thickness. There was some definite new bone formation on the right side where the bone had been removed four years previously. The scalp was freely movable over this tumor mass, and no inflammatory reaction was noted.

Blood and spinal fluid Wassermann reactions were negative Hemoglobin was 97 per cent

*Operations and Results*—In a two-stage operation, performed March 10 and March 17, 1920, I removed en masse what appeared to be a large osteoma (Figs 2 and 3) It lay directly over the longitudinal sinus where considerable difficulty was encountered in freeing the projecting spicules of bone from the underlying tissues The dura seemed to be frayed and torn, but no further exploration of the cortex was made at this time because the patient was tremendously shocked Following this procedure, he made a very satisfactory convalescence, returned to work as an expert accountant and continued at work

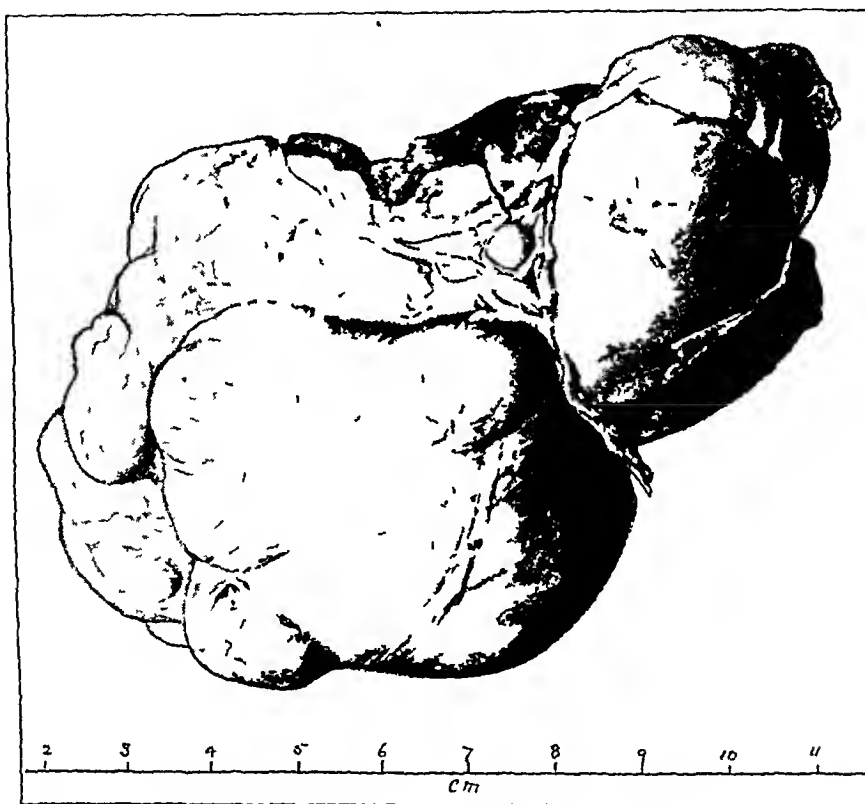


Fig 6 (Case 1)—Endothelioma underlying bony growth (compare Figs 2 and 3) The tumor growing within and from each side of the longitudinal sinus may be noted The tumor mass on the right side was much smaller than on the left It was removed en masse, with resection of the longitudinal sinus and falx cerebri, weight, 135 gm

until his final operation in March 1922 During this period, he was kept under bromids and phenobarbital (luminal) for much of the time He was irritable and difficult to live with In July, 1921 his irritability increased Oct 20, 1921, he had a very severe convulsion, the sixteenth, lapsing into a stupor which lasted for twenty-four hours Four weeks later, he had another similar convulsion the seventeenth Feb 23, 1922, the eighteenth and last convulsion occurred This was general and very similar to the two just cited

About this time, he became given to speculation, showed unsound business judgment, suicidal tendencies and again left home without apparent cause. Headache, while present, was not a prominent symptom. During this time, it was noted that there was never a depression over this large skull defect caused by the removal of the bony tumor in March, 1920.

Knowing that endotheliomas sometimes underlie bony overgrowths of the skull, I felt that the patient probably had such a tumor, which had not been disclosed at the former operation. Reexamination, March 7, 1922, revealed a recurrence of the bony tumor. Ossified areas could be palpated under the scalp in the region of the operative defect, some of which were free islands of movable bone, in no way connected with the surrounding skull but which undoubtedly had grown since the last operation.

Physical and neurologic examination at this time was again negative, except for the fact that the eye grounds showed a blurring of the disk margins.

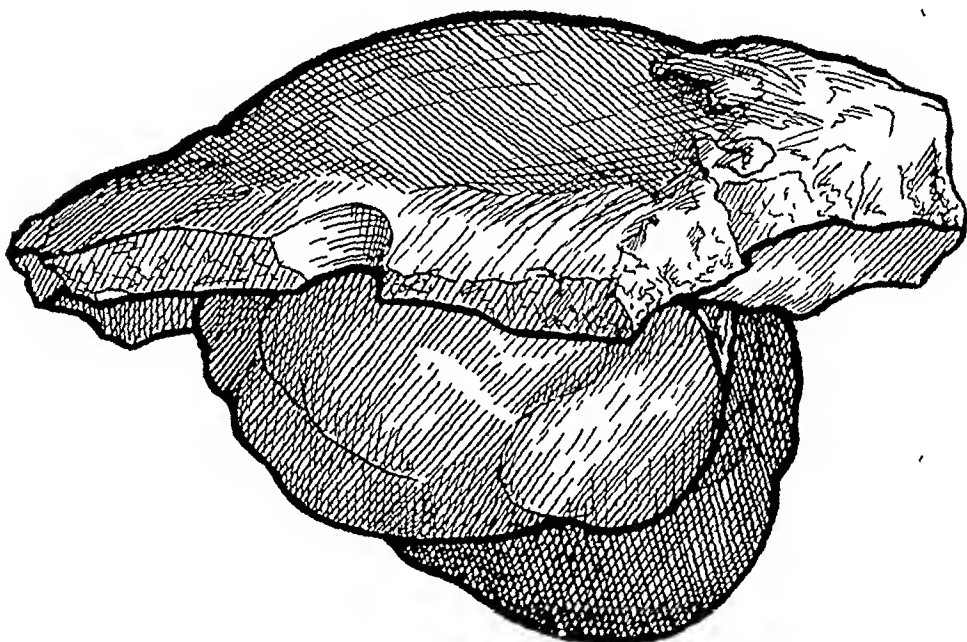


Fig 7 (Case 1) —Diagrammatic reproduction of complete growth, showing bony and soft tumors in relative position, entire weight, 240 gm

and congested vessels. This phenomenon was a recurrence, as the eye grounds had become practically normal following the removal of the bony growth two years previously. The main objective signs at this time were a recurrence of the tumor and extreme nervousness.

March 13, 1922, under local anesthesia, 35 cc of cerebrospinal fluid was removed from the right lateral ventricle and replaced by 35 cc of air. This procedure was carried out by the repeated removal of 5 cc of fluid, which was replaced by a similar amount of air until the total had been reached. The fluid was under moderate pressure and clear. The roentgen-ray examination of the ventricles (Figs 4 and 5) demonstrated that the air was trapped entirely in the right ventricle, which was displaced outward and downward. On the lateral view, a distinct notch could be seen on the upper surface of the anterior horn of the right ventricle, which was interpreted as being caused by pressure

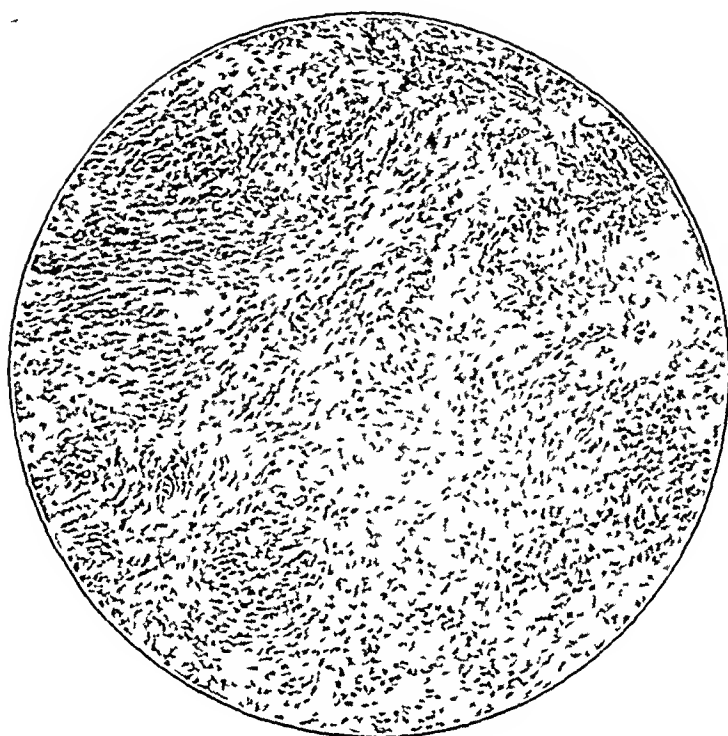


Fig 8 (Case 1)—Section of endothelioma showing systems of flattened cells tending to whorl formation



Fig 9 (Case 1)—Appearance of patient three months after last operation



from a lobular growth. The best explanation of the absence of air in the left ventricle and the displacement of the right outward seemed to be that there was a large growth projecting into each hemisphere, being larger on the left, so that the left ventricle was entirely closed, while the right was deformed and pushed outward.

March 20, 1922, the old operative field was reopened, and new bone was found growing throughout this region. There was also a recurrence of new bone from the margins of the skull defect, this was largely removed. The dura was then opened, and a tumor was found growing from both sides of



Fig 10 (Case 2) —Lateral view of skull, showing osteoma in right frontal region

the longitudinal sinus, involving it and apparently invading the brain proper. Several attempts to find a line of demarcation were unsuccessful.

The tumor on gross examination appeared to be malignant sarcoma, and sections were taken before closure. These sections were quite typical of endothelioma, and, March 27, 1922, the wound was again opened and an endothelioma weighing 135 gm was removed en masse (Figs 6 and 7). The longitudinal sinus was resected for a distance of about 10 cm and was removed with the tumor. The tumor was encapsulated, and the mass growing from the left side of the longitudinal sinus was about twice as large as that growing from the

right side. In fact, after the removal of the tumor, the left side of the cavity reached to the floor of the anterior fossa and seemed to have blocked completely the left ventricle. The part of the tumor excavation on the right side extended down about half way to the floor of the anterior fossa. A large fascia lata graft was placed over the defect and the wound closed without

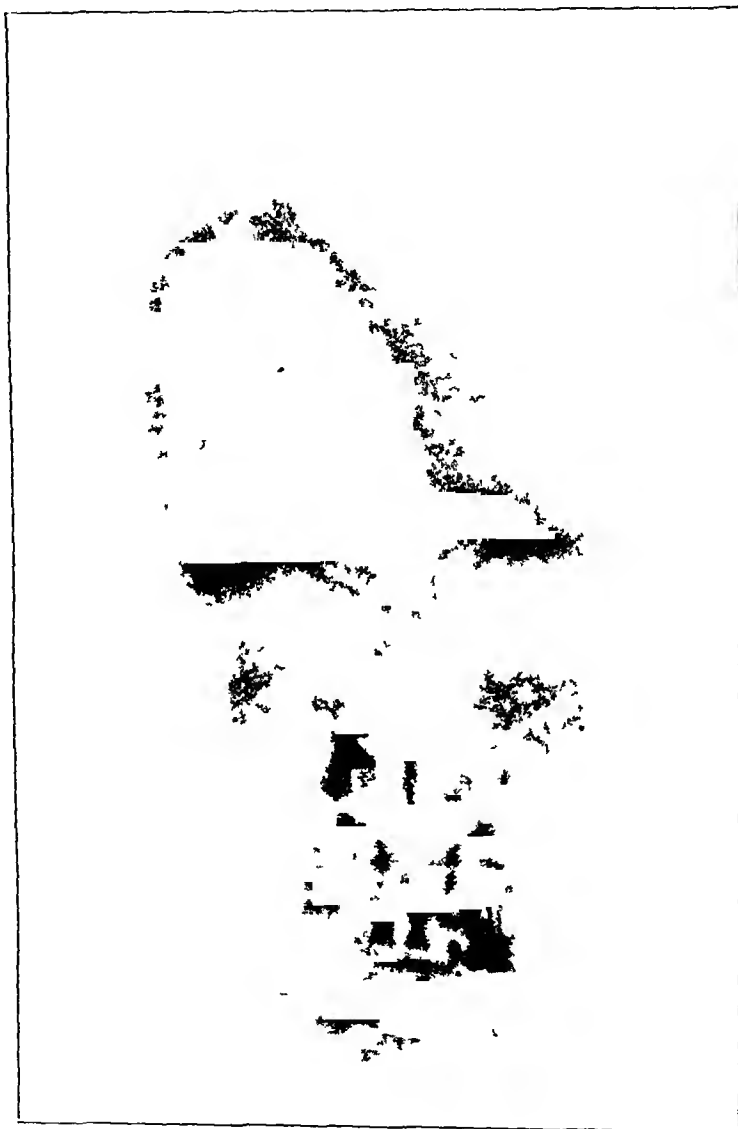


Fig 11 (Case 2)—Anteroposterior view, showing osteoma above right orbit, growth attached to both the supra-orbital wall and the inner surface of the frontal bone

drainage. The patient stood the operation well and left the hospital in two weeks.

*Microscopic Examination* (Fig 8)—Dr Roy Hammack of Los Angeles reported thus: "The tissue consists principally of whorls of flattened cells, sometimes spindle shaped with large oval nuclei. In some places the whorls

are not seen and the cells are arranged in long bundles. Frequently, there is seen at the center of the whorl a small blood vessel. Diagnosis: endothelioma of meninges."

*Comment*—Since the last operative procedure, the patient has been free from epileptic attacks, and the use of all sedatives has been discontinued. There is still undoubtedly some diseased bone about the edge of the skull defect, into which the scalp tends to dip. He has gained about 20 pounds in weight and is working again as an expert accountant (Fig 9). The mental symptoms described above have improved considerably, and his wife states that he is more normal than she has known him for years.

*CASE 2—History*—E. H. E., man, aged 48, married, retired chaplain, United States Army, referred by Dr. Edward Dillon of Los Angeles, was admitted to St. Vincent's Hospital, April 17, 1922, complaining of severe frontal headache and epilepsy. When a child, he had scarlet fever, and all his life he had had double otorrhea. He was also said to have had malaria and spinal meningitis in 1904, and pulmonary tuberculosis and influenza in 1918. There was no history of head injury. His present illness began insidiously, about four years previously, and was ushered in by frontal headaches which had gradually increased in severity. Insomnia and extreme restlessness had been present



Fig 12 (Case 2)—Appearance of tumor, showing nodular character of surface, no underlying endothelioma

for the last three or four years. The nervousness increased markedly, and, about two years previously, the patient suffered from mental confusion for a period of two or three weeks, after which normal mental processes were regained. About eighteen months before admission, he became deranged mentally, and, following a severe convulsion, lapsed into a state of complete unconsciousness which lasted for ten days. In a month's time, he again regained full mental activity. About two months before admission to the hospital, the patient again suffered from mental agitation. He also complained of numbness and weakness in the left arm and weakness in the left leg. During the last six months, there had been times when he did not articulate well. His temperature had always been normal during these attacks and his pulse about 80.

*Examination*—He was a tall man and much under weight, and he exhibited marked mental agitation. The head was rather large but quite symmetrical. Examination of the cranial nerves was negative, except for slight weakness of the left lower face. The eye grounds showed overfilling of the veins and some haziness of the disk margins, particularly on the right. No measurable swelling was made out. There was definite weakness of the grip in the left hand—left, 10, right, 80. The patient also complained of some

paresthesia in the left arm and hand, but no sensory changes were noted on objective examination. There was no hemianopia, and no astereognosis, right or left. The patient stood fairly well in the Romberg position. The gait was somewhat unsteady, but there was no definite ataxia. There was, however, moderate ataxia in performing the finger to nose and the finger to finger test, so that a question arose in the mind of one examiner as to whether the patient might not be suffering from a cerebellar lesion. The superficial reflexes were present and about normal. The deep reflexes were increased on the left side. The Babinski reflex was positive on the left, and negative on the right. There was no ankle clonus on the left or right.



Fig 13 (Case 2) —Postoperative lateral view, showing defect resulting from tumor removal

The roentgen-ray examination of the skull (Fig 10) revealed a dense shadow measuring about 2 cm in diameter. This shadow appeared to occupy an area in the right frontal region, about midway between the front of the orbit and the anterior clinoid process. In the anteroposterior view (Fig 11), it appeared above the middle of the orbit. There seemed to be a pedicle attaching this growth to the floor of the anterior fossa or roof of the orbit.

The laboratory findings were as follows: temperature, 98.6 F, pulse, 70, erythrocytes, 4,250,000, leukocytes, 6,996, differential count: mononuclears, 26 per cent, polymorphonuclears, 72 per cent, transitionals, 2 per cent.

hemoglobin, 70 per cent The blood Wassermann reaction was negative The results of urinalysis were reaction, acid, color, yellow, specific gravity, 1.012, albumin, faint trace, sugar, negative, casts, none The blood pressure was 101 systolic, and 68 diastolic

*Operation*—April 27, 1922, a right osteoplastic flap was turned down in the frontal region The flap was outlined with the base on the temporal side, and Frazier's technic for frontal approach to the pituitary fossa was employed There were many large blood vessels in the scalp, and considerable bleeding occurred because it was impossible to use a tourniquet On making the last trephine opening just above the orbit, the operator unexpectedly encountered the tumor itself However, the flap was turned down as outlined and the tumor was turned up with the flap The tumor was then removed with a small margin of normal skull (Fig 12) In doing this, it was necessary to enter the top of the right orbit and expose the orbital contents Even then, it was not certain that all the bony overgrowth had been removed When the flap was turned back, the dura, which was closely adherent to the tumor, was found to be shredded and torn A large dural flap was then turned back, and the frontal lobe



Fig 14 (Case 2)—Appearance of patient, ten days after operation, defect in right frontal region occasioned by tumor removal may be noted

inspected It was soft and somewhat discolored just under the site of the tumor, but nothing that appeared to be an endothelioma was found The wound was then closed in layers without drainage The patient made an uneventful convalescence All sutures were removed, May 4, and the patient left the hospital, May 10, 1922, two weeks after the operation

*Comment*—In reading the roentgenograms I was misled There appeared to be a pedicle attaching the tumor to the floor of the anterior fossa As a matter of fact, the tumor was directly attached to the lateral surface of the inner table of the skull, just back of the external angular process and to the roof of the orbit and was inadvertently encroached on in turning back the flap (Fig 13)

July 13, 1922, the patient (Fig 14) had had no further epileptic seizures and did not complain of headache He had become clear mentally and was much less nervous than before the operation He had gained about 40 pounds in weight, and the weakness of the left hand, arm and leg had practically disappeared

# ALTERATIONS IN THE CURRENTS AND ABSORPTION OF CEREBROSPINAL FLUID FOLLOWING SALT ADMINISTRATION<sup>1</sup>

FREDERIC E B FOLEY, M D

ST PAUL

Recent investigation has shown that, in experimental animals, both the pressure of the cerebrospinal fluid and the bulk of the brain can be reduced, either by the administration of hypertonic solutions intravenously,<sup>1</sup> or by the ingestion of salt.<sup>2</sup> The present paper deals with the alterations in the absorption and circulation of cerebrospinal fluid accompanying these changes in fluid pressure and brain bulk.

This fall of fluid pressure might at first glance appear to be due to decrease of brain volume. In such case no essential alteration in the processes of fluid absorption or secretion would need to be inferred. However, the diminution of brain volume does not wholly account for the lowering of fluid tension. This became apparent during the progress of one of the investigations mentioned above.<sup>2</sup> Certain observations, to be detailed later, were made which indicated that the fall of fluid pressure was actually due to a disturbance in the fluid-absorbing and fluid-producing mechanisms. There was also evidence of marked alteration in the normal currents of fluid in the ventricular system and cerebrospinal spaces.

Conjointly with these laboratory experiments, a clinical study of the uses of salt in conditions of increased intracranial tension was being conducted on Dr. Cushing's service at the Peter Bent Brigham Hospital.<sup>3</sup> This study gave abundant proof that the decrease of fluid pressure and brain bulk, produced in laboratory animals by salt administration, could be similarly produced in the human subject. In individuals whose cerebral ventricles were obstructed and dilated, salt ingestion was much more effective in lowering cerebrospinal fluid

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<sup>1</sup> From the Laboratory for Surgical Research, Harvard Medical School, Boston.

1 Weed, L. H., and McKibben, P. S. Pressure Changes in the Cerebrospinal Fluid Following Intravenous Injection of Solutions of Various Concentration, *Am J Physiol* **48** 512 (May) 1919, Experimental Alteration of Brain Bulk, *ibid* **48** 531 (May) 1919.

2 Foley, F. E. B., and Putnam, T. J. The Effect of Salt Ingestion on Cerebrospinal Fluid Pressure and Brain Volume, *Am J Physiol* **53** 464 (Oct) 1920.

3 Foley, F. E. B. Clinical Uses of Salt Solution in Conditions of Increased Intracranial Tension, *Surg, Gynec & Obst* **33** 126-136 (Aug) 1921.

pressure and diminishing brain bulk than was the case when these conditions were absent. This striking feature of the observations on patients was unexplained. It was suggested that absorption of the hydrops from within the ventricles would account for the response. However, absorption is thought not to occur in this situation.

It was believed that a systematic investigation of the changes in fluid absorption and circulation occurring in animals as the result of salt administration might be of considerable physiologic interest, and, at the same time, might offer a solution of the unexplained responses to salt administration seen in patients with obstructed and dilated ventricles.

#### SUMMARY OF THE NORMAL ANATOMY AND PHYSIOLOGY

It may be serviceable at this point to summarize briefly the accepted beliefs concerning the anatomy of the fluid spaces and the production, circulation and absorption of the fluid.

The ventricular system consists of the two lateral ventricles communicating with the third ventricle by means of the two foramina of Monro. The third ventricle in turn is joined to the fourth by the aqueduct of Sylvius. From here the ventricular system opens into the cisterna magna, a part of the subarachnoid space, by means of the foramen of Magendie, a median defect in the pial fold and epithelial roof of the fourth ventricle which extends from the posterior medullary velum in front to the medulla behind, and also by the foramina of Luschka, two openings at the extremities of the lateral pockets.

The choroid plexuses appear to lie free in the ventricles, though actually they are extraventricular structures, for they consist of masses of fine convoluted vessels lying outside the continuous layer of ependyma which constitutes the inner surface of the ventricular walls. These masses of vessels receive a complete investment of ependymal epithelium which thus becomes invaginated over them and excludes them from the ventricular cavities proper very much as the peritoneal covering of the intestines excludes them from the peritoneal cavity. Similarly, the sheets of ependymal epithelium which, after covering the choroidal vessels, extend back to the nervous tissue proper might be compared to the leaves of the mesentery. The ependymal leaves are termed the lamina chorioidea. In the third ventricle they are attached to the margins of the thalamus along a line known as the taenia thalami. From these attachments the invaginated choroid hangs down into the ventricle. The invagination is continued forward and laterally on both sides between the thalamus and fornix so that it projects into the lateral ventricles as the choroid plexus of these cavities. Here the upper leaf of the lamina chorioidea is attached to the margin of the fornix, while the lower leaf is attached to the dorsal surface of

the thalamus. The choroid plexus of the fourth ventricle is formed by a mass of vessels carried into the ventricle with an investment of epithelium from the thinned out roof extending below the cerebellum.

The extraventricular fluid spaces or subarachnoid space is made up of the irregular crevices formed by the irregularities of the brain surface and by the space intervening between the brain and skull. On the side of the brain this space is lined by a continuous mesothelial membrane, the pia, which closely invests the brain, dipping into the depths of all the sulci and other surface irregularities. On the side of the skull it is lined by another continuous mesothelial membrane, the arachnoid, which lies in contact with the dura and bridges the brain irregularities. This cranial subarachnoid space is continuous with the spinal subarachnoid space which in a similar way intervenes between the pia of the cord and the spinal arachnoid.

The main portion of the cerebrospinal fluid is a product of the choroid plexuses. That which is poured out in the lateral ventricles passes through the foramina of Monro to the third ventricle. Here the third ventricle choroid adds to the volume, and the current continues downward through the aqueduct and, with the addition from the fourth ventricle, is discharged into the subarachnoid space through the foramina of Magendie and Luschka. In the subarachnoid space there is a second source of supply of an entirely different sort, and one concerning which some doubt still exists. This comes from the perivascular spaces surrounding the vessels of the brain substance. These spaces exist as a defect between the walls of the cerebral arteries and veins and a surrounding envelop of mesothelial or glial cells. In the substance of the nervous tissue they join other spaces surrounding axons and larger nerve cells. On the surface they open into the subarachnoid space at the points of emergence of the vessels. Mott<sup>4</sup> first described a flow of fluid in these spaces as from the subarachnoid space to the brain substance and believed them to be channels of fluid absorption. Weed,<sup>5</sup> however, in a very comprehensive reinvestigation of this whole subject, concluded that under normal circumstances the flow is in the opposite direction, from brain substance to subarachnoid space (thus reverting to a conception favored previous to Mott's work), and that these spaces must be regarded as sources of cerebrospinal fluid. Without entering into a discussion of the evidence it may be said that it supports the latter conclusion.

From the subarachnoid space the fluid is absorbed into the dural sinuses along the arachnoid villi—small tufts of arachnoid cell masses

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<sup>4</sup> Mott, F. W. The Oliver-Sharpey Lectures on the Cerebrospinal Fluid, *Lancet* **2** 1, 79, 1910.

<sup>5</sup> Weed, L. H. Studies on Cerebrospinal Fluid, *J. M. Research* **26** 93 (Sept.) 1914.



which project into these blood streams through clefts in the dura forming the sinuses. In addition there is absorption along the sheaths of the cranial and spinal nerves, a stream which finally enters true lymphatic channels. There is no evidence in favor of absorption directly into the small vessels which traverse and are supported in the subarachnoid space.

#### EXPERIMENTAL INVESTIGATION

1 *Method*—Cats were used for all the experiments. The methods employed were various applications of the procedures used by Weed in his brilliant contributions in this field.<sup>5</sup> In a general way the experiments may be separated into two types: first, those dealing with the volume of fluid absorbed from the subarachnoid space and ventricles, or ventricles alone, after salt administration, together with determinations of the accompanying pressure change, and second, gross and microscopic identification of material precipitated from a foreign solution supplied to the subarachnoid space or ventricles following salt administration. The salt was administered as a 30 per cent solution of sodium chlorid, either intravenously or into an exposed loop of the duodenum. The animals were anesthetized with urethane. The particular details of the method in the several experiments will be detailed in each case.

2 *The General Effect of Salt Administration on Cerebrospinal Fluid Pressure and Brain Volume*—In a series of preliminary experiments which were a part of a former communication,<sup>2</sup> simple determinations were made of the cerebrospinal fluid pressure changes caused by salt. The pressures were measured in a manometer connected to a needle in the subarachnoid space introduced by occipito-atlantal puncture. The manometer was filled with physiologic sodium chlorid solution and set at 100 mm. of pressure. On giving the animal a small dose of 30 per cent sodium chlorid, either intravenously or into the duodenum, the cerebrospinal fluid showed an extensive and well sustained fall of pressure. A large series of experiments demonstrated that cats of equal size, given the same dose of sodium chlorid under like experimental conditions, give curves of pressure change almost identical, both as regards the rate of change and the extent of fall. The experiments revealed that the responses are quantitative reactions governed by the amount of salt administered.

An additional effect of these solutions is a decrease in the size of the brain, as first described by Weed and McKibben.<sup>6</sup> The shrinkage of the brain enlarges the cerebrospinal fluid spaces. In view of this fact, the question naturally arose as to whether in experiments of this

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6 Weed and McKibben. Footnote 1, second reference.

sort the fall of pressure recorded by the manometer might not be due simply to the dislocation of fluid from the manometer into the enlarging cerebrospinal fluid spaces and be indicative of no particular alteration in the fluid-producing and fluid-absorbing mechanisms

3 *Proof of a Disturbance in the Ratio Between the Pressures Under Which Fluid Is Absorbed and Produced*—The question was put to test by a series of experiments, as follows Two cats of equal size were used for each experiment To each animal a certain dose of 30 per cent sodium chlorid was given In one animal the cerebrospinal fluid pressure was recorded in a manometer of such bore that 100 mm of pressure change required a displacement of 1.06 c.c. of fluid, while in the manometer used for the other animal the same pressure change required a displacement of 0.26 c.c. of fluid That a disturbance in the ratio between fluid production pressure and fluid absorption pressure is induced by the administration of salt is proved by the fact that the

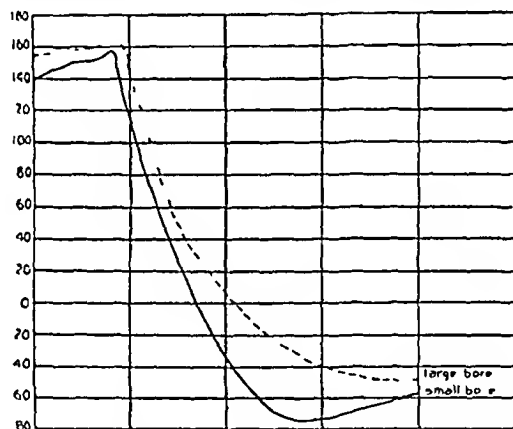


Fig 1—Curves of cerebrospinal fluid pressure of two cats, each of which weighed 3.8 kg and was given 10 c.c. of 30 per cent sodium chlorid solution intravenously In one animal the pressure was recorded by a manometer of such bore that 100 mm of pressure change required a displacement of 1.06 c.c. of fluid (broken line) In the other animal the pressure was recorded by a manometer of such bore that 100 mm of pressure change required a displacement of 0.26 c.c. of fluid (continuous line) The approximate parallelism of the curves and the nearly equal falls of pressure may be noted

curves of pressure change obtained by these different manometers parallel each other very closely and record pressure falls of about equal extent (Fig 1) Were the changes in height of the fluid columns in the manometers simply a function of volume change in the cerebrospinal spaces, then one manometer being four times the size of the other should illustrate a pressure change one-fourth as extensive and at a very much lower rate These changes have been demonstrated in numerous experiments of this sort and with manometers of various volume Within the limits of the absorption mechanism to increase

its rate of taking up fluid, the curves have all shown this parallelism. They show that salt administration induces a change of cerebrospinal fluid pressure which is largely independent of the volume change occurring in the cerebrospinal spaces.

4 *Features of the Reaction to Be Studied the Ferrocyanid Method*—That an increased osmotic value of the blood is the agency through which these changes are brought about, there can be no doubt. Determination of these changes has been undertaken in a clinical study apart from the present work.<sup>7</sup> We have not concerned ourselves here with the fundamental osmotic disturbances occasioned by the salt administered, but we have sought rather to determine the alterations in the mechanical movements of the fluid and changes in its absorption.

Concerning these alterations in absorption numerous questions arose. Was there simply an increased rate of absorption along normal channels, or were new avenues of fluid escape opened? As a first step toward the solution of these problems, use was made of the ferrocyanid reaction as employed by Weed.<sup>5</sup> The reaction consists in the precipitation by hydrochloric acid of Prussian blue (ferric ferrocyanid) from a mixture of solutions of iron ammonium citrate and potassium ferrocyanid, with later identification of the precipitated Prussian blue in the situations to which the solution was carried or absorbed. The method of applying the reaction in these experiments was as follows. Equal amounts of 2 per cent iron ammonium citrate and 2 per cent potassium ferrocyanid solutions were made up and kept separate until used. A manometer with tubing and needle attached was then filled with the mixture and set at from 100 to 120 mm. of pressure—the pressure usually to be anticipated in the normal animal. By means of occipito-atlantal puncture the manometer was connected to the subarachnoid space. After a brief period allowed for the establishment of equilibrium and determination of the animal's normal pressure, salt was administered. According to the size of the animal from 10 to 20 c.c. of a 30 per cent sodium chlorid solution was given either intravenously or into the duodenum. Incident to the giving of salt, the fluid showed the usual extensive fall of pressure. With falling pressure the ferrocyanid solution was displaced out of the manometer into the subarachnoid space. The amount of the solution so displaced was determined by the extent of pressure fall and the bore of the manometer used. At some period during the lowered pressure, usually when it had reached its full extent, precipitation of the Prussian blue and fixation of the brain were secured either by perfusion through the

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<sup>7</sup> The study referred to is being conducted on the medical wards of the Peter Bent Brigham Hospital (Wynn and Foley. Salt Administration as an Adjunct in the Intraspinal Treatment of Syphilis).

aortic arch with 10 per cent liquor formaldehydi containing 1 per cent of concentrated hydrochloric acid, or by immersing the head in 20 per cent liquor formaldehydi containing 2 per cent of the acid after first rongeuing away the greater part of the calvarium, leaving an intact dura. The perfusion, though it washed away the greater part of any precipitate in the vessels, assured immediate precipitation of the Prussian blue and fixation of the brain, and gave better material for histologic study. For the latter purpose, the tissue was washed, run through graded alcohols, and embedded in celloidin.

Paraffin sections are not suitable, for the dissolving of the paraffin in xylene releases the granules of Prussian blue which become free to float into situations in which they were not precipitated.

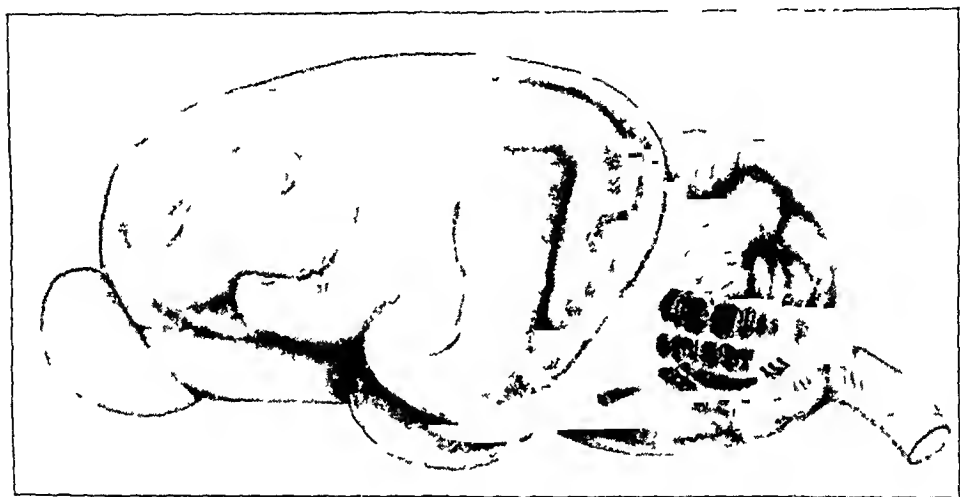


Fig 2—Drawing, showing the gross distribution of Prussian blue over the external surface of the brain, cat weight 3 kg, ferrocyanid solution supplied to subarachnoid space from large bore manometer, 20 cc of 30 per cent sodium chlorid injected into duodenum, 14 cc of ferrocyanid solution displaced in twenty-eight minutes, perfusion of aortic arch with 10 per cent liquor formaldehydi containing 1 per cent of concentrated hydrochloric acid. The abundant precipitate about the base and in the region of the tentorium may be noted. In comparison with controls the region of the sagittal sinus shows relatively little precipitate.

5 *Distribution of the Prussian Blue in Control Experiments*—The procedure in control experiments in which the animal received no salt was the same except that, in order to secure a displacement of the solution into the subarachnoid space, a higher pressure in the manometer had to be maintained. The brains of these normal controls showed a distribution of the precipitated Prussian blue, corresponding very well to the findings of Weed<sup>5</sup> in his studies of the normal absorption. In such control animals the precipitate occurred throughout the subarach-

noid space but in particular abundance about the large cisterns and basal pockets. It was carried upward over the cerebellar and cerebral hemispheres in the sulci but occurred in smaller amount over the convolutions. A relatively heavy deposit about the tentorium and sagittal sinus seemed to indicate a prominent current along these situations. It had extended forward about the base and out along the sheaths of the cranial nerves. In the latter situation the precipitate could be grossly identified some distance beyond the points of exit of the nerves from the skull. It was also present in the arachnoid villi, the chief channels of fluid absorption. Below the foramen magnum the spinal subarachnoid space showed the deposit for only a short distance, from 3 to 5 cm. below the atlas, practically no deposit being present. On section of these control brains the ventricles were found free from any trace of the deposit, provided a relatively low injection pressure had been employed. With pressures of from 300 to 400 mm. of the solution, however, there was definite precipitate in the fourth ventricle and lower part of the aqueduct, while with pressures of from 100 to 200 mm., this did not occur. Likewise, on microscopic study, the brains injected under high pressure showed a little deposit along the perivascular spaces for short distances, while in the case of the lower pressures, this did not occur.<sup>8</sup>

6 *Distribution of the Prussian Blue in Animals Given Salt*—The brains of animals given salt showed striking differences from the controls in the amount and distribution of the precipitate. In the first place, the usual salt administration experiment yielded a much more abundant deposit in certain of the normal channels than occurred in the controls. Brains taken at different intervals during injection showed that the solution had reached these sites more rapidly. Figure 2 is the reproduction of a drawing of the brain in such an experiment. The deposit about the basal pockets and along the nerve sheaths was very abundant and the penetration, even to gross examination, was obviously more extensive than in the controls. A much more abundant deposit in the choroidal fissure on the meshes of the tela chorioidea was also apparent. Grossly, the region of the sagittal sinus showed relatively less precipitate than the controls. An increased amount of precipitate in the arachnoid villi was not demonstrated, and, indeed, in the material studied, it was difficult to find the granules in these situations at all. Careful comparison by means of serial sections through a large number of villi, however, was not made, and the impression is based on the examination of the few villi encountered in single sec-

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<sup>8</sup> In his studies of the normal animal, Weed was able to secure injection of these spaces only by sudden extensive bleeding from the neck vessels unless very high (55 mm. Hg) pressures were employed.

tions In addition to these quantitative differences, the solution had passed downward in the spinal subarachnoid space for practically its whole length and was found along the sheaths of the lumbar nerves Microscopic examination revealed beautiful injections of the perivascular spaces deep along their course in the brain substance This observation is in accord with similar observations by Weed and McKibben<sup>6</sup> The injection of the perivascular spaces occurred even when the solution was supplied to the subarachnoid space under zero pressure, as was done in a few experiments by opening widely the suboccipital space and pouring the solution into the cistern (Fig 3) The fact that this injection of the perivascular spaces occurs even under zero pressure and with an open skull is very good evidence that the solution does not reach these sites because of artificially altered pressure relationships,<sup>9</sup> but is carried along the perivascular spaces by a process of true absorption The granules can occasionally be identified in the walls and lumina of the vessels surrounded by these injected perivascular spaces In many cases the deposit could also be identified about axons and nerve cells This was particularly true in the tissue immediately surrounding the lower and forward parts of the third ventricle Most striking of all, however, was the fact that on section of these brains there was an abundant deposit throughout the ventricular system The solution had been carried to the extremities of the lateral ventricles, both in the frontal and occipital lobes

7 *Consideration of Ventricular Volume Change as a Possible Cause of Retrograde Passage of Fluid to Ventricles*—The fact that the solution had been carried into the farthest reaches of the ventricular system under the influence of salt administration, while controls showed that this did not occur even when high injection pressures were used, made it seem possible that an intraventricular absorption of fluid was one of the direct effects of the salt The experiments described, however, did not give conclusive evidence of this The objection raised was that the shrinkage in the brain might have been accompanied by an enlargement of the ventricular cavities with aspiration of the solution from the subarachnoid space along the aqueduct, entirely in consequence of the altered volume relationships and in no way due to true absorption within the ventricles By the method employed it was impossible to say what part of the fluid displaced from the manometer had passed to the ventricles and what part had been absorbed from the subarachnoid space

In the experiments of Weed and McKibben,<sup>6</sup> striking alterations in the bulk of the brain had been observed following the intravenous

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9 As might be argued when a manometer at artificially high pressure is connected to the subarachnoid space

administration of hypertonic solutions. These findings were confirmed in a study<sup>2</sup> made later in which the salt was given by the gastrointestinal route, as well as intravenously. The former writers do not mention any change in the size of the ventricles, while in the latter study such changes were looked for and certainly were not striking. The chief alterations in the gross appearance of animal brains due to salt administration are in their external appearance. The convolutions become smaller and shrunken, while the sulci become wider and deeper. The whole mass contracts. After careful comparison of the ventricles of these shrunken brains with those from normal animals of equal size, we have been led to the conclusion that the ventricular volume remains almost constant.

8 *Direct Study of Ventricular Volume Changes and Intraventricular Absorption by Means of the Aqueduct Catheter Method*—These observations made it seem unlikely that enlargement of the ventricles was the cause of fluid passing up the aqueduct. An attempt was made, however, to determine definitely the volume of fluid displaced into the ventricles and to separate any absorption occurring here from that occurring in the subarachnoid space. To this end a manometer was connected to a small rubber catheter introduced along the aqueduct and of such size as effectively to seal itself off from the subarachnoid space by its contact with the walls of the aqueduct.<sup>10</sup> The procedure is technically difficult and only a certain proportion of the experiments attempted were successful. The animal was fixed in the prone position with the neck flexed far forward so as to make wide the space between the occiput and atlas. After dividing the postcervical muscles and freeing them from the occiput, the occipito-atloid ligament was divided by careful dissection and the arachnoid membrane opened with fine scissors. It was occasionally necessary to bite off a part of the occiput with the rongeurs in order sufficiently to expose the region of the foramen of Magendie. An inch or so of a No. 5 F flexible rubber catheter was used. A paraffin bead was molded onto the end of this small rubber tube in order to make it smooth and avoid injury to the walls of the aqueduct. The tube thus prepared was connected to a manometer of small bore filled to zero pressure with warm physiologic sodium chlorid solution. The catheter was then carefully inserted

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<sup>10</sup> This method of ventricular catheterization was first employed by Weed and Cushing (Am. J. Physiology 36:77, 1915) in a study of the secretory responses of the choroid plexus to posterior lobe hypophysis extracts. Their employment of the method was for the purpose of eliminating from the determinations of fluid formation rate the effects of volumetric changes of the subarachnoid space caused by the blood pressure changes incident to the injected gland substances and also for the purpose of diverting the fluid from its natural channels of absorption.

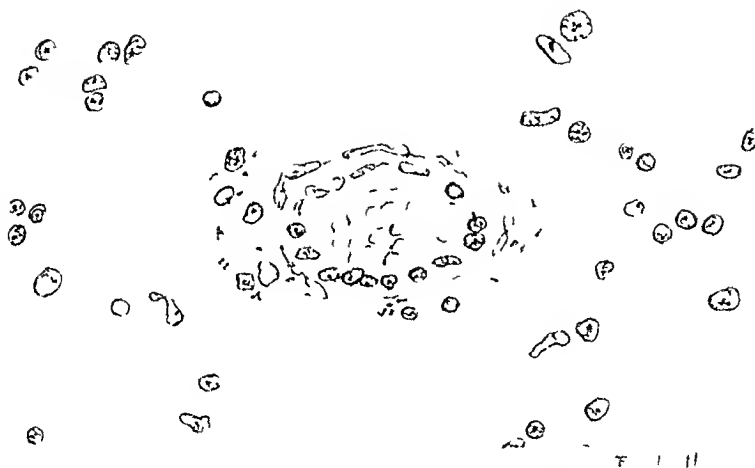


Fig 3—Drawing under high power to show the deposit of Prussian blue precipitated in a perivascular space to which the ferrocyanid solution had extended from the subarachnoid space. The ferrocyanid solution was supplied to the subarachnoid space under zero pressure by pouring it into the opened space between occiput and atlas. Fixation by immersion of brain in 10 per cent liquor formaldehydi containing 1 per cent of concentrated hydrochloric acid. The granules here are not deposited in the walls or lumina of the vessel as is often the case.





under the tip of the vermis and gently advanced a distance of from 18 to 22 mm. Tests disclosed that in the average sized animal this distance would put the beaded tip immediately under the quadrigeminal bodies, the narrowest and most substantial section of the canal. Figure 4 shows the catheter in situ and its relation to the surrounding structures. In the successful attempts, and in case the animal had not been exhausted from the long procedure, the column of fluid would show a typical pulsation when the manometer connection was opened. The pressure would gradually rise to a certain constant level and remain at this point. This pressure was usually considerably below the normal pressure recorded in the subarachnoid space of cats. This, I believe, may be attributed to the exhausting effects of the long operative pro-

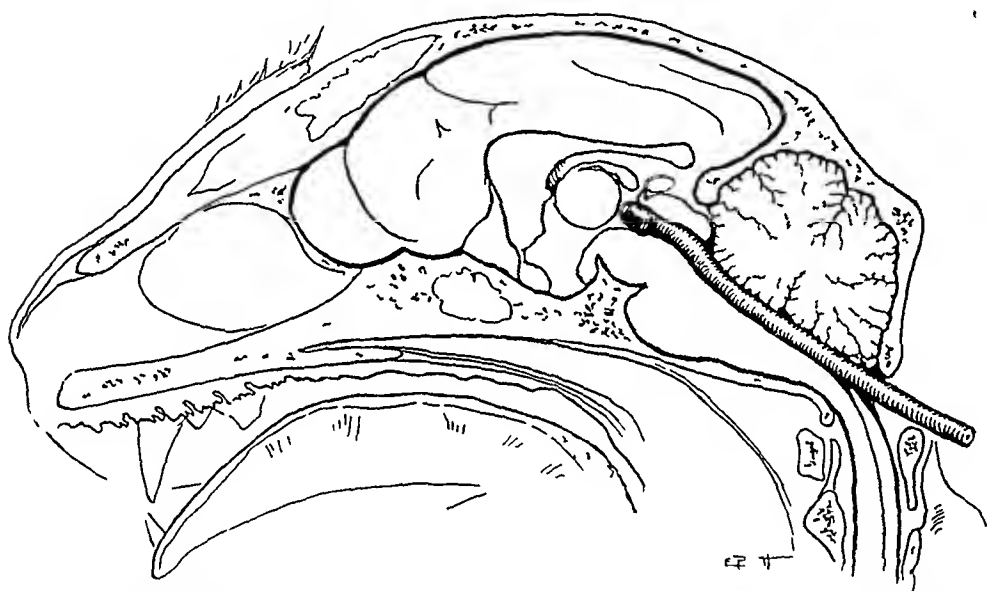


Fig 4—Sketch of midsagittal section through cat head to show the position and relations of the aqueduct catheter

cedure rather than to any physiologic difference between intraventricular and subarachnoid pressures. The majority of animals showed intraventricular pressures of between 70 and 130 mm of saline.

By this type of experiment, determinations were made of normal intraventricular pressures, and also pressure changes incident to the administration of hypotonic (water) and hypertonic (30 per cent sodium chlorid) solutions. By measuring the amount of physiologic sodium chlorid solution which was displaced out of the manometer, the volume changes of the ventricle plus intraventricular absorption accompanying the salt administration were also determined. Finally, the microscopic distribution of Prussian blue precipitated from a ferrocyanid mixture supplied directly to the ventricles was studied. Only

experiments are here considered in which no possible leakage occurred between the catheter and the walls of the aqueduct. The perfection of this connection was tested at the end of each experiment by careful search of the cerebellar cistern for granules of Prussian blue. In some brains, not used for microscopic study, the perfection of the connection was tested by injecting the ferrocyanid solution into the catheter under a pressure far greater than the normal. If the precipitate of Prussian blue could be found anywhere in the subarachnoid space it indicated leakage, and the experiment was discarded. Figure 5 is reproduced from a drawing of a cross section through the aqueduct and catheter, showing the latter in situ. It shows the intimate contact of the catheter with the aqueduct.

In brief, it may be said that under the experimental conditions described, intraventricular pressure has shown changes and responses to test solutions qualitatively similar to those recorded in the subarach-

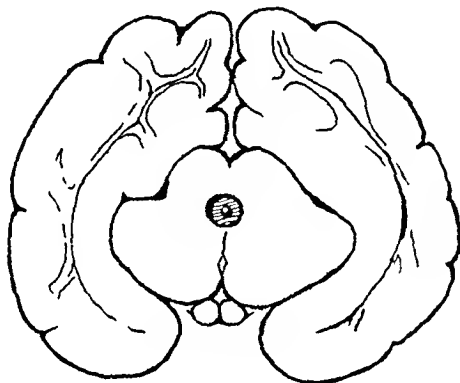


Fig 5—Transverse section through the aqueduct and catheter, showing intimate contact between catheter and walls of the aqueduct

noid space. The changes, however, are produced more rapidly and are not quite so well sustained. Curve A in Figure 6 shows the effect on intraventricular pressure of an intravenous injection of 30 c c of distilled water. A rise of 22 mm in pressure occurred—very much less than the rise of pressure usually produced in the subarachnoid space of an animal of this size following such a dose of water. Curve B shows the fall of pressure caused by an intravenous injection of 7 c c of 30 per cent sodium chlorid solution. Here the effect is more nearly comparable to similar changes produced in the subarachnoid space—a fall of 50 mm. The rate of fall, however, is considerably more rapid. In most cases the fall of pressure is preceded by a small preliminary rise.

Determination of the amount of fluid displaced into the ventricles following salt administration demonstrated quite conclusively that intraventricular absorption had occurred, for the volume of fluid so dis-

placed was far in excess of any possible ventricular volume changes. Details from a typical experiment may be cited. The manometer was of such bore that 100 mm of pressure change required a displacement of 0.2 cc of fluid, it was filled with physiologic sodium chlorid solution. The animal (cat weight 1.9 kg) was given 8 cc of 30 per cent sodium chlorid solution intravenously, a relatively large dose. The intraventricular pressure fell from 155 mm to minus 13 mm. This represented a fluid displacement of 0.34 cc. In relation to the volume of the ventricles of such a small animal this is a large amount of fluid. Though possible, it seems unlikely that a change of such volume occurred. In other experiments, however, either a manometer of larger bore was used, or after the pressure had fallen in the small manometer enough fluid was repeatedly added to raise the pressure from 20 to 30 mm above the existing level. By these means amounts of fluid in

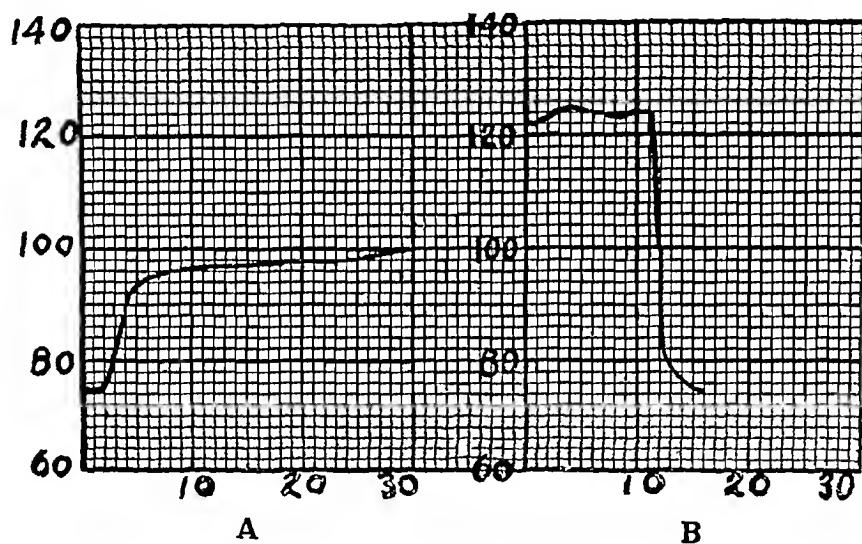


Fig 6—Curves of intraventricular pressure changes. *A*, the rise of intraventricular pressure following the administration of 30 cc of distilled water intravenously. Immediately after the injection is begun the pressure begins to rise rapidly. The elevated pressure is well sustained. Twenty-two minutes after the injection the pressure remains 22 mm above its level before giving the water, *B*, the fall of intraventricular pressure following the administration of 7 cc of 30 per cent sodium chlorid solution intravenously. Immediately after the injection is begun a precipitous fall of pressure occurs. Five minutes after the injection, the pressure is 50 mm below its previous level.

excess of 1.5 cc have been displaced into the ventricles and under technically perfect conditions, an intact connection of the catheter in the aqueduct having been demonstrated in all cases on which the conclusion is based. The experiments show that under the influence of salt the ventricles will take up fluid greatly in excess of possible change in ventricular volume. They made it quite clear that the passage of the ferrocyanid from the subarachnoid space to the ventricles, as in the

experiments previously described, was in consequence of true intraventricular absorption and was not due to an increase in the volume of these cavities

9 *Retrograde Absorption Through the Choroid Plexus and Ependyma*—In a previous section the gross differences were pointed out between the distribution of precipitated Prussian blue in animals receiving salt and in normal controls. Mention was also made of the microscopic finding of the deposit in the perivascular spaces, indicating a reversal of the fluid current along these channels and their behavior as absorptive mechanisms under the influence of salt. In those experiments the ferrocyanid mixture was supplied to the subarachnoid space under various pressure relationships. By employment of the microcatheter method, the solution was also supplied directly to the ventricles. Under these circumstances an abundant deposit of the Prussian blue was, of course, found in the ventricles. A description of the microscopic distribution of this precipitate within the ventricles as found in both types of experiment was deferred to this point in order, first, to present the experiments demonstrating that ventricular volume changes could not entirely account for its presence here, and secondly, to indicate that intraventricular absorption had actually taken place.

Greatest reliance has been placed in the sections taken from brains fixed by immediate perfusion with the acid containing liquor formaldehydi rather than in those fixed by immersion. In addition to these two methods of fixation, some of the brains in which the solution had been supplied to the subarachnoid space were prepared by first thoroughly washing away the ferrocyanid solution on the surfaces and pouring the fixative directly into the ventricles which were then laid open by tearing apart the corpus callosum. By this method not only were prompt precipitation and fixation assured, but the possible momentary osmotic effects of the perfusate in the vessels also was reversed. In all essential details the three methods have given the same microscopic distribution of the Prussian blue.

The deposit of Prussian blue is found lying free in the ventricular cavities, adherent to the ependymal epithelium and heavily deposited in the meshes of the choroid plexuses. It penetrates the farthest reaches of the ventricular system and in the lateral ventricles is carried far up into the angle between the fornix and thalamus, here lying between the ependyma proper and the laminae chorioideae. It lies in very intimate contact with the ependymal cells, and in many places is found deposited between them. This intimate relationship to the ependyma is most marked in the forward and lower parts of the third ventricle. Here the solution has everywhere extended beyond the ependymal lining, and the deposit is found in tissue spaces within the brain substance and in the perivascular spaces and lumina of the minute



Fig 7—Drawing under low power to show the precipitated Prussian blue in relation to lateral ventricle choroid plexus, same biam as in Figure 3. Section was taken transversely through the right lateral ventricle and shows a portion of the contained choroid plexus. Much of the precipitate no doubt was washed away. The abundant deposit over the ependyma and its relation to the surface of the epithelial cells of the plexus may be noted. All of the vessels show deposits about the endothelium and in places the precipitate occurs within the lumen of the vessel.

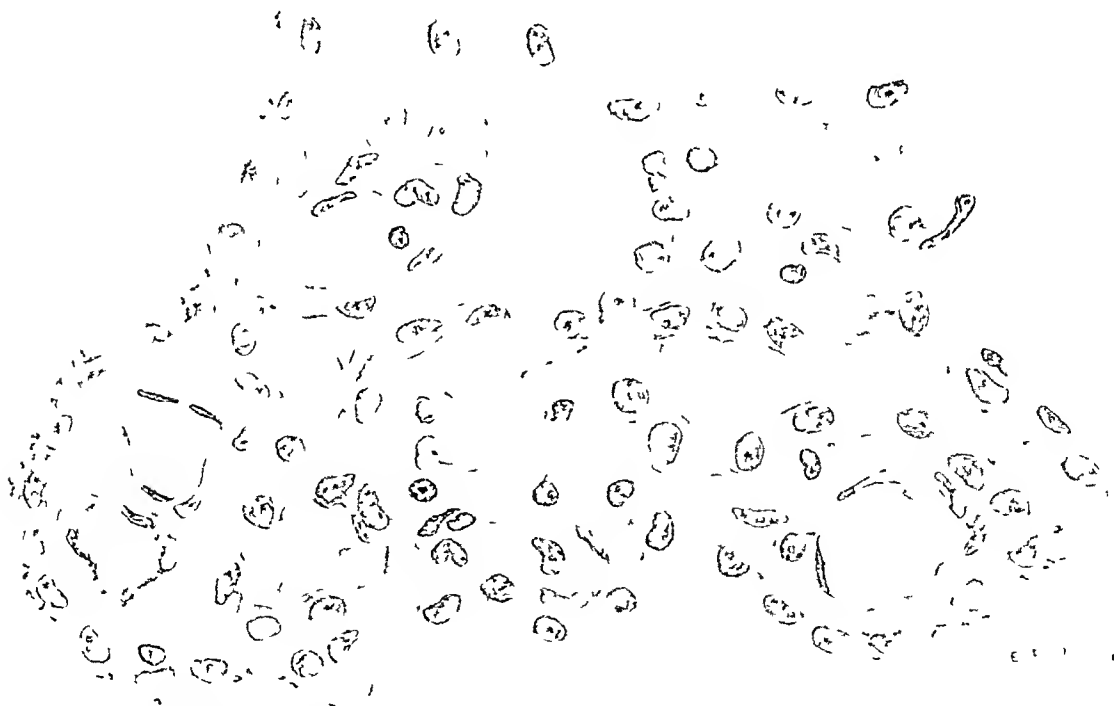


Fig 8—Drawing under oil immersion to show the detailed relationship of the precipitated Prussian blue to the structures of the choroid plexus. The abundant deposit over the surfaces of the cells and its apparent passage between the cells toward the capillaries may be noted. The vessel at the right shows the deposit lying between the epithelium and the wall of the capillary. In some situations the deposit appears to lie in the capillary wall, and in places it may be seen adherent to the inner surface of the endothelium. Any precipitate which might have lain in the lumina has been washed away by the perfusate. The animal was given 13 cc of 30 per cent sodium chlorid solution intravenously. The ferrocyanid solution was supplied to the subarachnoid space from a manometer of large bore. 161 cc of the solution was displaced into the subarachnoid space under diminishing pressure the injection having been begun when the cerebrospinal fluid pressure was at 142 mm. Brain fixed by perfusion of the aortic arch with 10 per cent liquor formaldehydi containing 1 per cent concentrated hydrochloric acid.



vessels in this region. That at least a portion of the solution reaches these sites by passage from the ventricle outward there can be no doubt, for it occurs when the solution is supplied to the ventricle alone, as well as when supplied to the subarachnoid space.

Most interesting is the distribution of precipitate in relation to the choroid plexus. It is intimately deposited about the epithelial cells of the tufts. From these situations it can be followed into the vessels of the tufts and is also found in the spaces intervening between the epithelium and the vessels. The intraventricular distribution of the Prussian blue as seen under low magnification is shown in Figure 7. The section was taken transversely through the right lateral ventricle and shows a portion of the contained choroid. Figure 8 shows the detailed relations of the granules to the epithelium of the choroid and the capillary vessels of the tufts as seen under oil immersion.

Certain minor differences may now be pointed out between subarachnoid and direct ventricular injections of the ferrocyanid mixture. In the case of subarachnoid injections abundant precipitate is found in the choroidal fissure clinging to the meshes of the tela chorioidea. In some cases the distribution of Prussian blue makes it appear that the solution has traveled along in this extraventricular situation out as far as some of the coarser tufts of the choroid, and has come along this extraventricular channel to lie in very close relationship to the smaller vessels of the plexus. Such granules would not represent an intraventricular absorption. That this channel is not the chief pathway of absorption into the vessels of the choroid is shown by the fact that absorption into these vessels takes place when the solution is supplied directly to the ventricle, with exclusion of these extraventricular channels about the tela chorioidea. Finally, in certain experiments, the aqueduct was obstructed by the catheter and the solution supplied, not to the ventricle, but to the subarachnoid space under zero pressure, by pouring it into the opened space between occiput and atlas. Under these circumstances the granules did not pass along between the laminae chorioideae to the smaller tufts but were present only about the larger vessels in the choroid fissure.

Finally, mention may be made of an alteration in absorption under the influence of salt consisting in the direct passage of fluid into the vessels traversing the subarachnoid space. In control animals there is occasional evidence of the same occurrence only when abnormally high injection pressures are employed. Controls injected under pressures of from 100 to 200 mm. of the solution showed no deposit in the walls or lumina of these vessels and the process cannot be said to be a part of normal absorption. All of the animals given salt, however, even if the ferrocyanid solution was offered to the subarachnoid space under zero pressure, showed granules deposited within these vessels.



## SUMMARY AND COMMENT

The experiments described demonstrate that the curves of pressure change in the subarachnoid space resulting from salt administration, though possibly influenced by decrease of brain bulk and enlargement of the cerebrospinal spaces, are, nevertheless, fundamentally expressions of a profound disturbance in the mechanism of cerebrospinal fluid absorption.

The altered absorption causes changes in the grosser currents of the fluid. There is an increase of the current forward about the base and downward into the spinal subarachnoid, while the current upward along the sagittal sinus is relatively diminished. The current of fluid in the aqueduct is completely reversed, a retrograde flow from subarachnoid space to the lateral ventricles being established. Determinations of the volume of fluid which so passes to the ventricles demonstrate that the retrograde flow is in consequence of intraventricular absorption and cannot be attributed to increase of volume on the part of the ventricles.

The disturbance in absorption itself consists in an altered rate of fluid passage along certain normal channels and the opening up of other channels through which normal absorption does not occur. There is an increased rate of absorption along the sheaths of the cranial and spinal nerves, with possibly decrease or cessation along other normal channels—the arachnoid villi. Conclusive evidence, however, is not offered in favor of the latter. Under the experimental conditions described a reversal of flow in the perivascular spaces has been shown to occur and confirms the similar observation by Weed and McKibben.<sup>6</sup> This reversal of flow is due to absorption into the capillaries of the brain substance. Absorption directly into the vessels traversing the subarachnoid space is also established.

Finally, it is shown that the intraventricular absorption induced by salt takes place through the choroid plexus into capillary loops of the choroid vessels and through the ventricular ependyma into tissue spaces, particularly in the region of the third ventricle. The fluid absorbed through the latter channel finally reaches the perivascular spaces and vessels of this region.

The details of these alterations in the absorption mechanism which result from salt administration offer an adequate explanation of the fact that patients with an obstructive hydrocephalus show marked symptomatic improvement following salt administration. The reaction in these cases is due to intraventricular absorption of the dammed-up fluid. The salt induces absorption of fluid within the ventricles where normally no absorption takes place.

The results of this study invite much speculation as to certain features of the reaction to salt administration which have not been touched on. There is certainly an increased volume of the total fluid containing spaces within the cranium, owing to the great decrease of brain bulk. This factor, coupled with the markedly increased absorption of fluid along certain normal channels, and, in addition, the establishment of drainage along new pathways, leaves unexplained the factor which compensates for this outpouring from the "closed box." A compensating factor either in the form of increased volume of the intracranial blood vessels, or a supply of cerebrospinal fluid from some source, seems to be a physical necessity. It is difficult to believe that such an extensive vascular readjustment takes place. A retrograde flow of fluid in the aqueduct and the establishment of intraventricular absorption make it seem unlikely that the compensating factor is in fluid produced by the choroid plexus. The same argument applies to the perivascular spaces as a possible source of supply.

A suggestion as to where the compensating source of fluid may be is found in the fact that the increased absorption along normal channels, and that along the new channels opened by salt administration, occurs at points where the process is probably one of osmosis. The absorption via the nerve sheaths is doubtless ultimately due to a process of osmosis through the capillary walls separating the blood stream from the lymphatic spaces into which the fluid is passed by the nerve sheaths. That which occurs backward into the perivascular spaces is most likely in consequence of an osmotic process occurring through the cerebral capillaries separating the perivascular spaces from the blood stream. The same sort of process must account for the passage of fluid into the vessels of the choroid and those traversing the subarachnoid space. At the arachnoid villi, on the other hand, normal absorption is thought to be a process of filtration and to take place in consequence of a higher pressure existing in the subarachnoid space than in the sinuses<sup>5</sup>. It seems possible that the great fall of pressure in the subarachnoid space incident to the administration of salt reverses the flow through the arachnoid villi which, under these circumstances, would become sources of cerebrospinal fluid supply and could act as the compensating mechanism. Our failure to demonstrate increased absorption about these structures, as a result of salt administration, is suggestive.

#### CONCLUSIONS

- 1 Salt administration establishes a new ratio between cerebrospinal fluid production and absorption pressures, resulting in decreased tension of the fluid in the subarachnoid space and ventricles of the brain.

2 Salt administration induces these changes in the mechanism of fluid absorption (a) intraventricular absorption through the choroid plexus and ependyma, (b) absorption by the capillaries of the brain substance with reversal of fluid flow in the perivascular spaces, (c) an increased rate of absorption along the sheaths of the cranial and spinal nerves, and (d) direct absorption into the vessels traversing the sub-arachnoid space

3 The administration of salt causes alterations in the gross currents of the fluid which are incident to the changes in the mechanism of cerebrospinal fluid absorption described above. Chief among these alterations in the currents of the fluid is reversal of flow in the aqueduct and ventricular system

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# THE RELATION BETWEEN OBLIQUE INGUINAL HERNIA AND WORKMEN'S COMPENSA- TION LAWS

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## I INTRODUCTION

Berger, in the opening sentence of his well known monograph, goes far to explain the entire foundation of the voluminous discussion as to hernia and accidents when he says, "There is not an individual who, having a hernia, at the moment when he noticed its existence, did not at once attribute it to an accidental cause, most often to an effort"

So we have a fixed idea inherent in the human race to combat, as well as the opinion of referees, boards and courts. Many surgeons believe that practically no hernias are of traumatic origin and that they should not be compensated, many labor leaders and social workers believe that all hernias are traumatic and that all should be compensated. The logic of the matter is just the same as it always is in the case of extremes, namely, that the truth lies somewhere between the two.

The present paper is the result of an effort to approach close enough to this intermediate point to form a fair and practical working basis. This effort is the outcome of a feeling that I have had for several years that the present legal and lay attitude is unsound, unscientific, at variance with firmly established medical facts, and that the attitude of courts and compensation boards is chaotic.

Several authors have attributed part of this confusion to the use of the word rupture as synonymous with hernia. A rupture is a tear, and what can cause a tear but an accident?—So there you are.

It has been shown that the English courts of the last century are responsible for a large part of the present difficulty. These courts floundered among directly contradictory medical witnesses, they did not have the benefit of sound scientific teaching which has been possible since hernia operations have become more common, and perhaps naturally they accepted "post hoc, ergo propter hoc" as the easiest argument. Medical men, indeed, had no very good ground for combating this attitude at that time. Our own courts and compensation boards have largely inherited the impressions of the English courts of a century ago and have not changed with the change of medical opinion.

The fault however, is perhaps not so much with our legal confreres as with the medical profession. We have not impressed on courts and

boards the new knowledge developed by vast numbers of hernia operations performed since the days of Lister

## II THE SACCULAR THEORY OF HERNIA

The connection between oblique inguinal hernia and the unobliterated processus vaginalis is the foundation of the present day medical conception as to the cause of hernia. Two French anatomists, Cloquet and Pellatin, in the eighteenth century called attention to the frequency with which this process persists. English writers, notably Kingdon and Macready, in the middle and latter part of the nineteenth century further called attention to this process and its connection with certain types of hernia.

It was not until 1899 that the full significance of the persistent processus vaginalis was definitely established by Russell, of Melbourne, Australia. It is interesting to trace briefly the development of Russell's work. At the Inter-Colonial Congress at Brisbane in September, 1899, Russell<sup>1</sup> read a paper entitled "The Etiology and Treatment of Inguinal Hernia in the Young." He contended that all inguinal hernias in the young are protrusions into a preformed unobliterated congenital sac—that the "acquired" hernia in the young was unknown. He cited in proof sixty hernia operations on children and infants in which the only procedure was obliteration of the sac. Russell's definite conclusions at this time are confined to children. However, even now he ventures the opinion that the same principle applies to adults, at least up to old age.

A year later, Russell<sup>2</sup> reiterated his views. He then had eighty cases of simple obliteration of the sac in children, with no failures, and he was more convinced of the case in adults. He concludes

"1 Inguinal hernia in young subjects is caused by the presence of a congenital sac, and there is no other cause.

"2 Acquired hernia in the young has no existence in fact.

"3 All cases of oblique inguinal hernia occurring at any time of life occur in subjects who are the possessors of a congenital sac.

"4 Subjects who have never possessed a sac, or in whom the sac has been efficiently removed, can never become the subjects of oblique hernia.

"I am able to find no evidence of any kind in favor of the belief that oblique inguinal hernia ever occurs at any age, independently of the presence of a congenital sac."

In 1902, Russell's<sup>3</sup> list of operations in children was 115, only two of whom later showed a "slight weakness." "There is no difference etiologically between the inguinal hernia of children and that of older

1 Russell, R. H. *Lancet* 2 353 (Nov. 18) 1899.

2 Russell, R. H. *Lancet* 2 1128 (Oct. 20) 1900.

3 Russell, R. H. *Lancet* 1 1519 (May 31) 1902.

people" He<sup>4</sup> then changed his former opinions and posited a congenital sac also for femoral, obturator and ischiatic hernias

Again, in 1905, Russell<sup>5</sup> expressed more firmly his previous views Speaking then of adults, he says, "I have never met with a case on the operating table that I have seen any reason to regard as being a case of genuine acquired hernia All my experience in surgery of adult hernia has been such as to force upon me the conclusion that there is substantially no difference between the hernia of adult life and that of childhood"

At that time, he believed that, even in adults, simple removal of the sac is nearly always sufficient

So far as I know, Russell's<sup>6</sup> last paper appeared in 1906 In this he says, "A normal inguinal canal is fortified against the occurrence of a hernia to a perfection and a degree of strength in extravagant excess of any demand that can be made upon it by the feeble intra-abdominal pressure"

Later, he<sup>7</sup> said -

"1 Where there is no developmental sac such as is provided in the case of the inguinal canal by incomplete obliteration of the funicular process, there can be no hernia

"2 The normally formed inguinal canal is endowed with a strength and retentive efficiency for resisting hernia, enormously in excess of any demand that can be made upon it by the mere intra-abdominal pressure unaided by the presence of a sac"

Russell soon received an active and militant supporter in Murray of Liverpool Murray<sup>8</sup> published six articles from 1906 to 1907 and a book in 1910 He quotes dissections of 100 unselected adults without history of hernia Twenty-one had a potential hernia sac, 1 e., an unobliterated processus vaginalis, seven had more than one sac, and one had four Later, he reports 200 dissections Forty-seven bodies had sacs, often multiple, so that there were sixty-eight sacs in all

Murray says, "I firmly believe in the truth of Russell's contention as to the congenital origin of the so-called acquired hernia"

### III THE LITERATURE

The saccular theory being now well launched, the opinions of medical writers on this and allied points connected with the etiology

4 Russell, R H Lancet **1** 707 (March 12) 1904

5 Russell, R H Intercolon M J Australasia **10** 408-424, 1905

6 Russell R H Lancet **2** 1197 (Nov 3) 1906

7 Russell, R H Lancet **1** 683-685, 1907

8 Murray R W Lancet **2** 1246, 1904, Liverpool M-Chir J **26** 207-210, 1906, Lancet **1** 363-365, 1906, Brit M J **2** 1385-1389, 1907, Lancet **1** 1113, *ibid* **2** 445 (Aug 17) 1907, Hernia Its Cause and Treatment, Ed 2, London, 1910

of hernia are of interest. In this review it has been obviously impossible to read all the articles on hernia, but I have carefully read every available article listed in the *Index Medicus* (about 200 in all), the title of which in any way suggested a discussion of etiology, trauma compensation, etc. Only those articles which were found to have a special bearing are noted below.

BRITISH AND COLONIAL LITERATURE (EXCLUDING RUSSELL AND MURRAY)

Kingdon<sup>9</sup> (London, 1864) draws attention to the importance of the unobliterated processus vaginalis and holds it connected with certain phases of the development of hernia. He describes the popular belief in regard to strains, etc., and describes patients who think they strained themselves and noticed a hernia a few days later, and considered the strain to be the cause. The beliefs and statements of the patients in 1864 were evidently exactly the same as they are now. He says, "There is no evidence whatever to show that muscular exertion in health and by itself is ever a cause of hernia. All cases spring fundamentally from the same cause, namely, fault in the peritoneum. Hence it is concluded that hernia is a disease and not an accident, a pathological condition, not a mechanical lesion" (This in 1864).

Macready<sup>10</sup> (London, 1893) "There are a great number of ruptures of which the contents are in an unobliterated part of the processus vaginalis, and it is impossible to distinguish these clinically, except in rare instances, from ordinary ruptures and not always even by dissection. We are seldom able to use correctly the term acquired."

"The name rupture also is open to objection because it implies an opinion as to the mode of formation of the disease which has long since proved to be erroneous."

"There is no positive assurance that intra-abdominal pressure causes hernia at a given moment of time in a person whose abdominal wall is normal."

Stiles<sup>11</sup> (Edinburgh, 1901) "It is more than probable that the majority of all oblique inguinal herniae in adolescents and young adults are congenital."

Oliver<sup>12</sup> (Newcastle, 1902) "Take what is known as rupture or hernia, which occurs with greater frequency in persons whose work obliges them to be long on their feet and who are exposed to sudden strains—the lifting of heavy weights, etc. What is said of it applies equally well to varicose veins in the legs. Both of these may be partially the result of position assumed by the individual when at work, or the result of strain that he is exposed to, and yet it would scarcely be right to make the occupation responsible for an affection, the result of an inherent weakness in the abdominal wall which allowed a portion of the intestine to protrude, giving rise to a rupture, or for an ill-nourished condition of the walls of the veins in the legs whereby the blood vessels become distended and deformed."

Sheen<sup>13</sup> (Cardiff, Wales, 1904) "Under ordinary circumstances, the only explanation of the initial sudden appearance of a hernia lies in the existence of a preformed sac."

9 Kingdon, J. A. *Tr. Med. Chir. Soc.*, 1864, p. 295.

10 Macready, Jonathan. *A Treatise on Ruptures*, London, 1893.

11 Stiles. *Brit. M. J.* 2 599, 1901.

12 Oliver, Thomas. *Dangerous Trades*. New York, E. P. Dutton & Co. 1912.

13 Sheen, W. *Brit. M. J.* 2 60, 1904.

The conditions Sheen considers necessary for trauma to be regarded as a cause of hernia are

"1 Trauma must be a sudden general contraction, compressing the abdominal contents, as in lifting a too heavy weight, or in resisting a blow, or possibly a general abdominal squeezing, as in a buffer injury. A localized blow on one part of the abdomen cannot cause a hernia

"2 Must be small at first

"3 Must appear immediately after the accident

"4 Must be accompanied by acute pain and tenderness at the site of the hernia, and by the formation of a small lump there

"5 Must be so acute as to compel the patient at once to leave his work and seek medical aid

"The association of hernia with trauma is exceptional"

Chiene<sup>14</sup> (Edinburgh, 1907) "For practical surgical purposes, all oblique inguinal hernias are primarily due to a congenital or preformed sac"

Corner<sup>15</sup> (London, 1907) gives observations on 700 hernias in children. Thirty-four per cent of these children had multiple hernias. (An indication of the importance of the congenital influence)

Sheen<sup>16</sup> (Cardiff, 1909), in discussing the difficulties of a lay arbitrator, says, "In the midst of a mass of ill-understood technicalities following the line of least resistance and giving judgment to the workman in these hernia cases the post hoc, ergo propter hoc view is naturally considered the easiest one

"The sudden first appearance of a hernia in the sense that it constitutes an accident arising from excessive strain is a very rare but not impossible event. Its sudden complete development in a pathological sense is improbable because the peritoneum cannot stretch suddenly to form the sac

"The true traumatic hernia must be small at first. I believe that the sudden first appearance of a scrotal hernia is impossible. That the individual ceases work I believe is practically always true"

Deansley<sup>17</sup> (Wolverhampton, 1910) "There are conclusive reasons for believing that all, or almost all, inguinal hernias are congenital. There is absolutely no reason to suppose that oblique inguinal hernia ever arises without a preexisting sac formed by a patent funicular process"

Telford<sup>18</sup> (England, 1912) gives an able, academic discussion of the saccular theory, agreeing entirely with Murray, Russell, etc

Roughton<sup>19</sup> (London, 1912) "I believe that all oblique inguinal hernia sacs in children and young adults are formed in this way [i.e. through a congenital sac] and that they are really never acquired"

Moffatt<sup>20</sup> (Cape Town, South Africa, 1912), draws the following conclusions

'1 Hernia is a congenital defect

'2 A repeated intra-abdominal pressure makes it obvious

'3 The pressure is caused by the performance of physiological functions and muscular effort

14 Chiene Brit M J 2 1389, 1907

15 Corner, E M Lancet 2 78 (Jul 13) 1907

16 Sheen, W Practitioner 83 334-338, 1909

17 Deansley Brit M J 1 1487, 1903

18 Telford Med Chron 56 17, 1912

19 Roughton E W Lancet 1 1534, 1912

20 Moffatt H A Transvaal M J 8 5-13, 1912-1913



"4 In the small number of cases in which a wrench, a special effort or a strain is honestly thought to have caused the hernia, the effort or strain has only made it apparent, not in any way caused it"

Barnett<sup>21</sup> (Belfast, 1904), discussing the examination of an actual claim case says, "1 Was there a preexisting weakness, congenital or otherwise, which would markedly predispose to such an injury? If there was, then the accident was only an existing agent

"2 Was there a preexisting congenital sac so slight as not to be noticed by the individual, but only requiring a slight strain to make it apparent? If so, the man cannot claim that the accident was the chief cause

"3 Was there a preexisting hernia which the employee paid no attention to until an injury to the part drew his attention to it? Careful questioning and examination will reveal the truth"

Bennett<sup>22</sup> (Glasgow, 1917) "The position on examination seems to be that there is general acceptance of the view that the great majority of indirect hernias are of congenital origin—a view that is supported by embryological evidence, while the case for even a few of them being acquired rests on nothing more substantial than belief"

Handley<sup>23</sup> (London, 1918) "Murray and other surgeons have shown beyond doubt that the sac in nearly all inguinal hernias has existed from the beginning of life It is a matter of chance, depending on the degree of intra-abdominal pressure, whether the preexisting sac is ever made evident by the descent into it of some of the abdominal contents"

Turner<sup>24</sup> (London, 1919) accepts the saccular theory of hernia and advocates an operative technic based entirely thereon He says, "I consider that the congenital origin of the sac in the vast majority of inguinal herniae has been conclusively proved"

He notes that many British soldiers developed a hernia during training or in the field who also gave a history of hernia in infancy or childhood The change from a sedentary to a military life evidently made these hernias, which were present in childhood, again become apparent to the person He operated on many soldiers in whom, according to the history, hernia had been present only a few days or weeks and "never once found any bruising or other sign of trauma"

"The men (British soldiers) were practically all strong and well developed and otherwise healthy, and I strongly believe, in all these cases, that, though the hernia appeared to have been acquired, the sac was a congenital structure"

#### FRENCH LITERATURE

Bouradel (quoted by Berger<sup>25</sup>) "In the great majority of cases, hernia is not a sudden accident It is an infirmity prepared by a congenital malformation"

Duchamps,<sup>26</sup> 1900 "Hernia prepared by a special disposition, congenital or acquired, appears often after a slight effort, which is its occasional cause and not its efficient cause It should not be considered an accident of work and put as a charge on the employer"

21 Barnett, Norman Textbook of Surgery, London, Heinemann, 1914

22 Bennett Glasgow M J 88 134 (Sept) 1917

23 Handley Practitioner 100 466 (June) 1918

24 Turner Inguinal Hernia, London, F & A Churchill, 1919

25 Berger, P Rev de chir 33 577-617, 1906

26 Duchamps Loire med 19 258, 1900

Jamin,<sup>27</sup> 1902 "There are very rare exceptions when hernia should be considered an accident of work"

Thiltges<sup>28</sup> (Belgium, 1903) "The great majority of hernias of force have been prepared for a long time and come on the occasion of work, not by work

"The vaginal process is very often unobliterated, and a very little force, cough, or the least effort of any kind of work will force a piece of intestine into it The hernia is only a late congenital hernia and does not deserve indemnity"

Sole,<sup>29</sup> 1904, stated that in 1895 the German Bureau of Insurance allowed thirty-two out of 400 hernia claims Sole allows three classes of accidental hernia (1) wounds of the abdominal wall, (2) massive contusions (run over accidents, etc), (3) direct contusions

Sole strongly insists that, in sudden hernia, pain must be "not vague, slight and moderate, but violent, like that produced by the blow of a whip, a pain which it is impossible to conceal and which can lead to syncope Pain persists several days and the part remains tender

"The protrusion of a hernia is not the same thing as its formation It is simply the last phase of its development

"All irreducible hernias are not recent"

Berger<sup>30</sup> (Paris, 1906) has published the most elaborate and complete monograph on hernia in connection with "accidents of labor" that I have seen It covers about eighty pages of the *Revue de chirurgie* and should be carefully studied in the original The work is based on carefully compiled statistics of more than 10,000 hernia cases in a large Paris clinic Only a few extracts can be given to show the trend of Berger's authoritative teaching

"We know that hernias, in the immense majority of cases, are not the result of an accident, that it is the accidental or professional effort which has revealed their existence Hernias, in fact, result from a slow process which has for its real origin a constitutional defect of the abdominal wall, or a congenital weakness, consisting of a true malformation, or acquired and depending on a gradual weakening of the muscle and aponeurotic planes of the wall This imperfection, congenital or acquired, localized in certain anatomical regions, shows itself by the existence of weak points where are concentrated the effects of abdominal pressure, necessarily increased by physiological, professional, accidental and pathological efforts Under the influence of these causes, incessantly repeated, the weak point is forced to yield and a hernia is produced

"This extrusion of viscera, unfolding the peritoneum in the abdominal wall and forming the hernial tract, is quite gradual The hernia insinuates itself slowly in the thickness of the abdominal wall and has existed there a long time, perfectly recognizable to the eye and hand of one accustomed to such examinations An accidental circumstance in determining a tension a little more painful than usual draws it to the attention of the patient"

Berger found in 117 subjects who noticed a hernia immediately after an accident or effort, and who held such to be the cause, that there were one or more additional hernias in ninety-six out of the 117 which had not been noticed

'True hernias of force, those which are determined by an accident, a traumatism, an effort in a normal individual, are an exception—a very rare exception The great majority of hernias which are referred to an accident

<sup>27</sup> Jamin These de Paris 1902

<sup>28</sup> Thiltges, N Presse med belge, Brux 55 786-791, 1903

<sup>29</sup> Sole J de med de Paris 16 27, 1904

have as the original cause a predisposition created by a weakening of the wall or by a congenital defect which has only hastened the appearance or more often only made manifest the existence of a hernia which already existed unperceived

"The existence of a double hernia is incompatible with the idea of a hernia of force

"Most oblique inguinal hernias which develop slowly, spontaneously, or under the influence of an accident have a congenital origin"

Berger gives very valuable suggestions for the detailed examination of claim cases, the detection and weighing of evidence of old hernias and predisposing conditions and valuable suggestions as to the weighing of the professional evidence in the case, and directions for making reports of practical utility to attorneys, etc. Other forms of hernia receive careful attention

An editorial<sup>30</sup> in the *Journal de médecine de Paris*, 1907, gives the following extracts from French court decisions

"When the hernia shows no characteristics of a hernia of force, i e., suffering sharp, intolerable and prolonged it is not an accident of work"

A lower French court and a higher court of appeal held against an applicant in whom a hernia appeared suddenly in the course of work, because the alleged cause represented no considerable effort (In the French courts, an adequate force is apparently necessary)

Another lower court, confirmed by a court of appeal, rejected a claim because the man continued his work after he felt the pains, showing how moderate the effort was and the insufficiency of the effort to determine a hernia

Another French court says hernia appearing after an effort, normal in the course of labor, does not constitute an accident of labor

Moreau<sup>31</sup> (Belgium, 1909) "A hernia of force is produced at once, at a given moment in a sound man under the influence of an effort, unusual, well determined and violent, with the accompaniment of sharp pain

"The hernia of weakness appears unconsciously, little by little, under the influence of repeated efforts, constituting really a professional disease, or it shows itself following an ordinary effort without great pain"

Tierlinck,<sup>32</sup> 1909 "In hernia of force, pain is sharp and localized in the hernial orifice, there is malaise, weakness and often syncope. Continued work is impossible. Must see a doctor the same or the next day. Pain lasts several days

"A strangulated hernia should not be considered due to a strain at work unless it is shown that the strain surpasses the normal limits for the particular work"

Poissonnier<sup>33</sup> 1911 "If the worker is indisposed to such a degree that the hernia would have to appear eventually under the influence of the slightest effort, the court finds itself in the presence of the evolution of a disease and not an accident"

Reclus,<sup>34</sup> 1912 "Has the accident produced in the injured the severe general and local phenomena which are always, as far as clinical observation teaches us, the consequence of a traumatic hernia? If the facts are negative, your conscience is at rest

30 Editorial, *J de med de Paris* 19 53, 1907

31 Moreau, C *Med d accid du travail*, Paris 7 140-145, 1909

32 Tierlinck, A *Ann Soc de med de Gand* 89 31-47, 1909

33 Poissonnier, M *J d sc med de Lille* 1 529-537, 1911

34 Reclus, P *Rev gen de clin et de therap*, Paris 26 769-771 1912

"We know that traumatic hernia is characterized by a violent pain such that the injured cannot stand up. He falls and cannot rise without falling again. His face is anxious, covered with cold sweat. One finds, in the groin, a small swelling, very painful, irreducible and in which each movement, each pressure exaggerates the suffering. Often on the following day, one finds edema and traces of ecchymosis."

## ITALIAN LITERATURE

Caccioppoli,<sup>35</sup> 1910 "The theory that a strain can produce a hernia is antiquated, hernia is a disease. A force, to cause a sudden hernia, must be sudden, abrupt and intense. Such a hernia produces such an intense and violent pain as to completely incapacitate any one for work."

(Further Italian literature on this subject has not been available.)

## AMERICAN LITERATURE

Manley<sup>36</sup> (New York, 1892) "My own experience has led me to regard hernia of every description, as always, in every instance, being attributable to so-called predisposing causes solely and alone, to congenital antenatal conditions, the active cause being an incident only and nothing more, bearing about the same relation to the infirmity that a local injury does to a cancerous growth."

"I am able to say, without any qualification whatever, that hernia is never attributable to trauma alone unless the violence be applied by some hard, heavy, sharp pointed instrument, which either punctures or rends the abdominal wall and that, when hernia appears after the application of an ordinary force it can always be demonstrated that it had previously existed, the accident or injury being an incident only in its evolution."

After an exhaustive review of the literature then available Manley was "unable to find a single case of purely traumatic hernia recorded."

"I have never seen a case in which there was proof that a hernia was forced through any of the natural passages by inflicted violence among those who have been run over, who have been crushed in various ways, have fallen from a considerable height or sustained blows over any part of the abdomen."

"Physical force in itself can very seldom cause an abdominal hernia without at the same time inducing mortal changes."

"It may be stated with emphasis and certainty that the direct application of concussive force is never a primary cause of hernia."

"There is no evidence that ordinary bodily traumatism aggravates the herniated condition, except in those cases in which it is applied immediately over the herniated area."

"A more general knowledge of the above facts by the general mass of the profession should, while in no way interfering with the fullest measure of justice being meted out to the injured or crippled, nevertheless greatly restrain those who have a hernia from making it the sole cause for demanding extortionate sums or instituting criminal proceedings."

Marcus<sup>37</sup> (Boston, 1896) "The general opinion is that hernia is produced by some violent strain, or accident, for which in the general mind the term

<sup>35</sup> Caccioppoli. *Med ital* 8 519, 1910

<sup>36</sup> Manley, T. H. *Herniac, Operative and Nonoperative*, J. A. M. A **19** 182 (Aug 13) 1892, *The Relation of Physical Violence to Hernial Protrusions Through the Abdominal Walls*, *ibid* **19** 387 (Oct 1) 1892

<sup>37</sup> Marcus, H. O. *Operation for the Cure of Hernia Viewed from a Medico-legal Standpoint* J. A. M. A **27** 979 (Nov 7) 1896

rupture is a synonym, that is, a sudden giving way of the parts involved. A superficial study of the case might lead one often to arrive at this conclusion. This is so exceptional that it represents a very minute fraction of the total."

Coley<sup>38</sup> (New York, 1902) "So far as known at present, traumatic herniae are produced or caused only by direct, heavy application of force, at the site where the force was applied."

Coley states that in 50,000 cases at the Hospital for Ruptured and Crippled in New York there were only four in which direct trauma was a probable factor, and even in these the proof was not absolute. "It is extremely doubtful if traumatism alone, without an open funicular process in the hernial canal, can ever produce a hernia."

Brown<sup>39</sup> (New York, 1904) reports the case of a jockey, 18 years old, whose horse reared and fell over backward on him. The patient immediately became very ill, with severe pain, vomiting and collapse. Dr. Brown saw him a few minutes later and found a typical, small strangulated inguinal hernia. This was reduced by taxis. There was no previous history of a hernia. Operation two weeks later revealed a small sac containing omentum. Operation and recovery were uneventful. (This case is abstracted somewhat fully, because it illustrates what any one would accept as a traumatic hernia. Even here, however, a direct blow by some part of the saddle and also the presence of a congenital sac are possible. Note that all the criteria of a traumatic hernia, such as excessive violence and immediate serious illness, are present.)

Morgan<sup>40</sup> (Augusta, Ga., 1904) "Traumatism is occasionally a true cause of hernia, but only by direct violence. One case in every 10,000 would be a liberal estimate for hernia as the result of injury."

"No concussive force, however severe, or simple increase of intra-abdominal pressure can ever be satisfactory as the primary and sole factor in the production of any form of abdominal hernia."

"The supposed sudden appearance of an acquired hernia is, in my opinion, always dependent on a mistaken observation."

His conclusions are

"1 I think it is established by experience and a preponderance of testimony from our best authorities that indirect violence of any character can never be regarded as the cause of a hernia."

"2 Severe direct injury cannot be considered a causative factor, except where the muscle wall of the abdomen is ruptured by the injury, and the hernia appears at the point of injury."

"3 It is highly probable, if not absolutely sure, that in all cases of so-called traumatic hernia where ordinary force only is applied, the true cause will be found in congenital defects and not as a result of trauma."

Fowler<sup>41</sup> (Brooklyn, 1906) "The fact that the formation of the most important part of the hernia, namely the sac, occupies a period of time extending, in some instances, over many years, and is frequently a congenital condition, and the further fact that the occurrence of the protrusion results from a gradual traction and pushing forward of a certain isolated portion of the

38 Coley Progr Med 2 40 (June) 1902

39 Brown, F T Ann Surg 39 287-290, 1904

40 Morgan, J B Am J Surg & Gynaec 18 26-28, 1904-1905

41 Fowler, G R Treatise on Surgery, Philadelphia, W B Saunders Company, 1906

abdominal wall, should decide the question against the contention that hernia is to be considered as resulting from an accident, particularly as a number of such hernias depend upon peculiar local conditions, such as the existence of lipomas, etc

"A hernia may make its first appearance after an injury. If, under these circumstances, it at once becomes strangulated, it may be deemed to be traumatic in origin"

Fowler limits traumatic hernias to those following operation

Andrews<sup>42</sup> (Chicago, 1907) "I am very skeptical of the role of even severe injuries in producing inguinal or femoral hernias or any other form of hernia. I firmly believe that nine out of ten of the so-called acquired hernias of the railroad man, or any man in laborious occupation, after some fall or sudden jump from a high place or some crushing force—I do believe that the patient in that case either already had the hernia and did not know it or else that it was preexistent and he merely had an increase in size of it

"There is often a time in the history of a hernia when even a physician does not determine that it is present. After some strain, the patient will finally discover that he has a small inguinal lump or the physician will perhaps discover it. This does not prove, however, that it has just come into existence"

Butte<sup>43</sup> (Philadelphia, 1907) "The extrusion of bowel or omentum and its entrance into the sac are but the last of a long series of antecedent and preparatory changes. Repeated muscular effort forms the way for the actual protrusion of the hernia. The last effort is the culminating etiological factor—the straw that broke the camel's back"

Eccles,<sup>44</sup> 1908 "In the majority of cases, a hernia is of gradual and slow formation, and this without any tearing or breaking of tissue, such as is clearly indicated in the use of the word rupture

"It is decidedly rare for a hernia to be formed suddenly, and the very fact that the applicant for compensation gives the history of a rapid development of his protrusion should of itself be a cause of suspicion

"A person may aver that he has developed a protrusion not suddenly but at a period which is remote from the date of the accident, believing it to be caused by it. If it is in one of the usual positions for a protrusion, the inguinal, femoral or umbilical region, it is highly probable that the accident had little or no part in its causation"

Outten<sup>45</sup> (St. Louis, 1908), who probably had a larger experience as a railroad surgeon than any other man, says, "Any surgeon who has made a careful study of the surgery of violence, that is, railway and allied injuries, must and will come to the conclusion that traumatic hernia is so extremely uncommon as to leave doubt as to its verity in almost every case

"Sudden muscular effort can never be the cause of rupture. I have never seen but one case of inguinal rupture in which the rupture was seemingly the product of an immediate injury

The consensus of opinion with the great majority of authorities on this subject is against the possibility of the occurrence of hernia as a result of trauma

42 Andrews, E. W. *Railway Surg. J.* **13** 169 (Jan.) 1907

43 Butte, H. J. *New York M. J.* **86** 739-742, 1907

44 Eccles. *Hernia*, New York: William Wood & Co., 1908

45 Outten, W. B. *Interstate M. J.* **15** 334-349, 1908

"Medicolegally, then, the existence of traumatic hernia has not been proven" Coley<sup>46</sup> (New York, 1909) "Hernia is a disease rather than an accident

The congenital defect, then, is the main cause of a hernia, while the immediate or exciting cause plays but a minor role"

Harbaugh,<sup>47</sup> 1909 "The symptoms of a true traumatic hernia are easily recognized and differentiated from hernia which passes into a sac which has been in the process of construction for a more or less long period of time"

Allport<sup>48</sup> (Chicago, 1909) "I am not a believer in traumatic hernias Ecchymosis, boggy swelling, local tenderness and congestion, mild febrile movement, etc, should just as certainly accompany genuine violence in the hernial region as in any other part of the body"

Magruder<sup>49</sup> (Baltimore, 1910) "In most instances in which hernia is supposed to have been acquired as the direct result of an injury or a strain, careful investigation will prove that it existed before, but was either not recognized or, being rendered larger by increased strain, was brought suddenly to the individual's notice

"Localized blows over the abdomen, owing to the fact that they do not cause compression, cannot give rise to hernia

"From a study of reported cases and a general review of the literature, it is fair to conclude that injury is never the direct and only cause of inguinal or femoral hernia but may be the means of increasing the size of, or calling attention to the presence of, a hernia which already exists In order that hernia can follow as the direct and only result of an injury, independent of previous weakness or congenital sac, some very severe and penetrating wound to the abdomen must take place"

Wood<sup>50</sup> (Philadelphia, 1910) agrees entirely with Russell and says, "Trauma may be an exciting cause of hernia in rare instances but only provided a sac already exists True traumatic hernia is of very rare occurrence

"It is impossible for a hernial sac to form instantly, under ordinary circumstances"

Hessert<sup>51</sup> (Chicago, 1910) "A close study of this region at operation and examination of the sacs in situ and after removal forces upon one the conclusion that many of these cases were of congenital origin The chief etiological factor underlying the development of oblique inguinal hernia in fully three fourths of the cases can be traced to the preexistence of a congenital sac, the result of faulty closure of a part or the whole of the vaginal process This proposition has been sustained in the last 100 operations in the author's practice"

He reports studies on 503 infants, with the following result vaginal process open on both sides in 26.6 per cent, right side open in 12.7 per cent, left side open in 5.1 per cent, or 44.4 per cent of infants have an open process on one or both sides

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46 Coley, in Keen, W. W., and Da Costa, J. C. *Surgery Its Principles and Practice*, Philadelphia, W. B. Saunders Company, 1909

47 Harbaugh, C. H. *Med Exam & Pract* 20 16-19, 1909

48 Allport, W. H. *Internat J S* 22 162-167, 1909

49 Magruder, W. E. *Claims Arising from the End-Results of Injury*, Baltimore, 1910

50 Wood, A. C. *Month Cycl & M Bull* 3 11, 1910

51 Hessert, W. *Surg, Gynec & Obst* 10 252-256, 1910, discussion pp 327-329

Bevan<sup>52</sup> (Chicago, 1910) says, in a discussion of Hessert's paper, "I am quite of the opinion that the view taken by Russell and Dr Hessert and others is quite correct, that the preformed sac is the most important factor in both femoral and inguinal hernias"

Connell<sup>53</sup> (Oshkosh, Wis, 1910), in discussing Hessert's paper, says, "It reinforces my opinion that practically all oblique inguinal hernias are of congenital origin"

In discussing Pillon's paper, to be noted later, Connell says, "The occurrence of true traumatic hernia is unusual I have never seen such a case and I would say that, if it does occur, it must be with such a severe injury that the hernia will probably be of small moment"

Foltz<sup>54</sup> (Fort Smith, Ark, 1910) says, "Accidental direct traumatic herniae are curiosities"

McCandless<sup>55</sup> (St Louis, 1910) says, "Nearly all oblique hernias are of congenital type and depend more on the preexisting condition than upon any present energy for their production"

Bendixen<sup>56</sup> (Davenport, Ia, 1910) says, "No hernia should be considered an industrial accident with the exception of the true traumatic variety, i e, the direct result of external violence"

"No employer should be held responsible for an anatomic malformation of his employee and should not under any circumstances be made to pay damages for said defect"

MacLennan<sup>57</sup> (Chicago, 1910) gives an elaborate and convincing proof of the saccular theory of hernia and says that it "goes a long way to prove that the essential factor in the production of a hernia is the presence of a pre-existing sac"

He calls attention to the fact that, if one examines a patient with recurrent hernia at a time when it is reduced, it is impossible to force intestine or omentum into the sac by any degree of pressure of the surgeon's hands on the abdomen

Pember and Nuzum<sup>58</sup> (Janesville, Wis, 1910), illustrating the point just mentioned by MacLennan, report the case of a laborer, 55 years old, whose abdomen was severely crushed between a boat and some fixed object The compression ruptured the intestine, and he died He had an old hernia, but nothing was forced into the sac by this severe crush

These authors have performed an elaborate series of experiments on cats, and, as a result of this and their clinical experience, say, "In true traumatic hernia, you have the history of a most severe injury and the profound shock that always accompanies it, the protruding mass or swelling, and often ruptured internal viscera The indications are so plain that he who runs may read

"Traumatic hernia is not likely to be produced by a blow which is short of lethal, unless a punctured wound is produced"

"A blow which is sufficiently severe to produce hernia would be certain to do sufficient violence to other abdominal organs to prove fatal"

52 Bevan A D Surg Gynec & Obst 10 328, 1910

53 Connell, F G Surg Gynec & Obst 10 327, 1910

54 Foltz Railway Surg J 17 337, 1910-1911

55 McCandless, W A Railway Surg J 17 333-337, 1910-1911

56 Bendixen, P A Railway Surg J 17 330-333, 1910-1911

57 MacLennan, A Surg, Gynec & Obst 10 57-59, 1910

58 Pember and Nuzum Wisconsin M J 9 663-673 1910-1911



Reineking<sup>59</sup> (Milwaukee, 1910), discussing Pember and Nuzum's paper, says, "So far as true traumatic inguinal, femoral or umbilical hernia is concerned, I have never seen a case"

"The diagnosis of traumatic hernia should not be made unless it can be based on the following conditions If seen soon after the occurrence of the injury, there should be pronounced local symptoms If seen later, the diagnosis should not be made unless the surgeon is previously familiar with the patient's condition before the injury for the reason that, although the patient may be perfectly honest, a partial hernia may have been present without his knowing it"

"I have never seen a case which I could consistently call traumatic hernia at one of the hernial openings"

Harrington<sup>60</sup> (Milwaukee, 1910), discussing Pember and Nuzum's paper, says, "The first and essential principle we should get in mind is that the presence of a hernia following force is not sufficient to bring it under the classification of traumatic hernia"

"You cannot get a traumatic hernia without severe shock and without the symptoms of an unusual and violent injury"

Corwin<sup>61</sup> (Pueblo, Colo, 1910) writes a convincing paper on this subject, and quotes Charles Mayo, as follows "It is extremely doubtful if traumatism alone, without the funicular process in the inguinal canal, can ever produce a hernia The trend of surgical opinion is rapidly growing in the direction of considering practically all cases of hernia to be due to a preformed sac of congenital origin, which forms the great predisposing cause for hernia"

Corwin also quotes A F Jonas, as follows "I believe that no man will have an inguinal hernia if his vaginal process is completely obliterated"

Frank<sup>62</sup> (Kentucky, 1911) says, "If we have a peritoneal covering, that in itself is absolute evidence that we have not a traumatic hernia"

Bloch<sup>63</sup> (Louisville, Ky, 1911) draws the following conclusions

"1 Traumatic hernia is very uncommon"

"2 The occurrence of traumatic hernia is impossible without a predisposing condition"

"3 Traumatic hernia always presents unmistakable symptoms"

Dugan<sup>64</sup> (Kentucky, 1911) in discussing Bloch's paper, says, "Any claim of traumatic hernia which is not accompanied by intense pain coming on suddenly is not well grounded most with intense shock"

Corwin<sup>65</sup> (Pueblo, Colo, 1911) refers to some experiments of his own, showing the strength of the inguinal canal, and says, 'For a viscus to force itself through a healthy abdominal wall by muscular contraction or jar seems well nigh impossible'

He believes that, in an unsound body, an accidental hernia may occur with a readiness depending on the degree of the abnormality, but "accidental hernia in a sound body is improbable"

Pilon,<sup>66</sup> 1911 "A patient who complains of hernia, several days after the accident, had a hernia before the accident occurred" (Connell's discussion of this paper is noted above)

59 Reineking, H Wisconsin M J 9 671, 1910-1911

60 Harrington Wisconsin M J 9 670, 1910-1911

61 Corwin, R W Colorado Med 7 283-289, 1910

62 Frank, Louis Kentucky M J (Jan 15) 1911

63 Bloch, O E Kentucky M J 9 84-88, 1911

64 Dugan Kentucky M J 86 (Jan 15) 1911

65 Corwin, R W Am J Surg 25 93-95, 1911

66 Pilon, P C Railway S J 18 276-282, 1911-1912

Fort<sup>67</sup> (Louisville, 1911) "I do not believe that there is any such thing as traumatic hernia by indirect violence"

Miller<sup>68</sup> (Villa Grove, Ill., 1911) "I do not think we have such a thing as traumatic hernia. A traumatism which has sufficient force to produce an inguinal hernia in a ring that is normal in its size and without inherent weakness would inflict a fatal injury"

Moschowitz<sup>69</sup> (New York, 1911) shows how an inguinal hernia really can be traumatic. He relates the case of a young Russian who, to escape army service, was taken by his friends and laid on the floor. One man sat on his head, another man ran a finger into the groin. This caused so much pain that the subject fainted. He was taken home and told to take snuff and drink yeast to make him vomit. He sneezed and vomited all night and the next morning had a hernia. It is interesting to note that the army surgeons suspected some such performance and accepted this young man just the same.

The same author, in 1915, presented a very convincing scientific proof of the importance of the preformed sac and the rarity of traumatic hernia. This paper should be read in the original. Moschowitz says, "My aim in writing this paper is to prove a fact at which I arrived after many years of careful study, namely, that traumatic hernia does not exist." He then makes an exception to this statement to include only postoperative hernias and those which are due to direct blows of more or less sharp instruments, and those in which there is a distinct laceration of the tissues of the abdominal wall.

Plummer<sup>70</sup> (Chicago, 1915), who has had, for many years a large experience as chief surgeon of the Rock Island Railway, publishes an important paper on this subject, which should be read in the original. He states that he has seen many cases of severe injuries to the abdomen in people who have been run over by automobiles, injured in railroad wrecks, etc. He has seen all kinds of ruptures of the abdominal viscera, but he has never seen an inguinal hernia follow such an injury, even in the severest cases. He says, "A single strain can never be the cause of a hernia. Even if predisposing causes are present, a hernia cannot be forced down as the result of a severe strain without stretching and lacerating the surrounding tissue so as to cause great pain as well as edema and ecchymosis. The patient will at once cease his occupation and call attention to the fact that he is injured."

"Cases where the employer should be held liable are rare exceptions."

Duff<sup>71</sup> (Chicago, 1915) "Ninety-eight per cent of all hernias do not come under the Workmen's Compensation Act"

Levings<sup>72</sup> (Wisconsin, 1915) "Hernia, to be classed as one of effort or due to traumatism, must occur for the first time during unusual effort or traumatism. The hernia must be small, tense, painful and disabling, in other words strangulated."

Brickner<sup>73</sup> (New York, 1915) "Herniae through umbilical, inguinal or femoral canals are never traumatic, we believe (except, to be quite exact, in such rare instances in which a penetrating injury actually occurred to these canals)"

67 Fort, F. T. *Railway Surg J* 18 412-419, 1911-1912

68 Miller, J. M. *Railway Surg J* 18 417, 1911-1912

69 Moschowitz, A. V. *Ann Surg* 54 265, 1911

70 Plummer. *Chicago M Rec* 37 307, 1915

71 Duff, R. R. *Illinois M J* 27 184-188, 1915

72 Levings, A. H. *Wisconsin M J* 14 273-276, 1915

73 Brickner. *Am J Surg* 29 223 (June) 1915

"Herniae discovered at one of those sites were present before the strain, fall or blow, potentially, or small, or, most often, fully developed but perhaps unnoticed"

Salmon<sup>74</sup> (Ashland, Ky, 1915) presented an able discussion of this subject at the meeting of the Chesapeake and Ohio Railway. Dr George Ben Johnson of Virginia offered a resolution which was unanimously adopted at this meeting, endorsing Dr Salmon's paper and expressing the unanimous opinion of the association that hernia is never traumatic.

Smith<sup>75</sup> (Randsburg, Calif, 1916) quotes a personal letter from the California Industrial Accident Commission, as follows: "The rupture must occur at once following an unexpected blow, fall or strain greater than the individual meets in the regular run of his occupation. The production of the rupture must be accompanied by pain that disables the patient at once and continuously, and makes immediate recourse to the surgeon imperative. The patient must, furthermore, furnish clear evidence of the nonexistence of the hernia previous to the alleged accident."

Locher<sup>76</sup> (Baltimore, 1916) "The sac is the terminal result of a gradual process and not the result of a single sudden strain or effort."

Bacon<sup>77</sup> (Miami, Ariz, 1917) relates an interesting phase of fourteen years' experience in a mining community. From 1903 to 1910, he saw no case of hernia in which accident was claimed as a cause. From 1910 to 1914, he saw one case in which recent injury was claimed. In 1915 the Workmen's Compensation Law was passed, and in this year six persons claimed that a hernia was due to a recent injury. In 1916 there were ten such cases, and in 1917 there were seventeen such cases up to September 1.

Da Costa<sup>78</sup> (Philadelphia, 1918) "In true traumatic hernia, there are violent pain, collapse, vomiting, inability to walk or stand, and the mass does not return to the belly on recumbency, but must be reduced by taxis or operation."

Blake<sup>79</sup> (Boston, 1919), discussing a case of hernia claimed to have been contracted in playing baseball, says, "I doubt very much if a hernia is caused from sliding to first base or a sprint around the bases unless there was a previously large ring, probably a potential hernial sac."

Mock<sup>80</sup> (Chicago, 1919) gives an able discussion of this question in his valuable textbook. On business and philanthropic grounds, he takes a broad view of the advisability of caring for the afflicted persons, although he apparently accepts the current medical opinion concerning the influence of a congenital sac, etc.

Lauffer<sup>81</sup> (Pittsburgh, 1919) "Hernia in a preformed sac is a disease, irrespective of the circumstances accompanying the first appearance of a mass in the groin. Peritoneum cannot be pushed out to form a sac by any single impulse."

74 Salmon, J M. *Virginia M Semimonth* 20 290-292, 1915-1916

75 Smith, W B. *Calif State J M* 14 351, 1916

76 Locher. *Spectator* (March 23) 1916

77 Bacon, J E. *Southeastern Med* 1 9-12 (Sept) 1917

78 Da Costa, J C. *Modern Surgery*, Philadelphia, W B Saunders Company, 1918, p 1275

79 Blake, J B. *Internat Clin* 2 90, 1918

80 Mock, H E. *Industrial Medicine and Surgerv*, Philadelphia, W B Saunders Company, 1919

81 Lauffer, C A. *J Indust Hygiene* 1 177-182 (Aug) 1919

"Acquired hernia as encountered in industries is likewise a gradual process, and, while its discovery may cause a surprise to the patient, it has really been a longer time on the way than he knows of

"Noted general and leading industrial surgeons are unanimous in their opinion that a hernia is to be classified as a disease, except the rare cases of general traumatic hernia

"Over 4,000 hernias have been compensated in Pennsylvania [in the first three years of the compensation law], or more than the real cases of traumatic hernia that have occurred in the western hemisphere since Columbus"

Colcord<sup>82</sup> (Clartown, Pa, 1919) "The wrong idea of hernia, promulgated by English surgeons and English courts of the nineteenth century and continued by our own courts and compensation boards, has been productive of much injustice to employers of labor

"The force which produces traumatic hernia is tremendous, far beyond the ordinary strains of labor

"To have a real traumatic hernia we should have (1) direct violence at the point of hernia, causing such severe injury to the abdominal wall as to produce a hernia at once or in a few days, (2) indirect violence, causing enormous increase in intra-abdominal pressure far out of all proportion to the lifting, straining, etc, of ordinary labor

"A hernia first complained of by the patient after an accident or a heavy lift does not prove that the accident caused the hernia. It discovered it to the patient, if honest, or if dishonest it afforded him an opportunity to sell an old hernia to his employers"

Saunders<sup>83</sup> (Fort Worth, Tex., 1918) "It is inconceivable that the sac of a hernia can be formed by one violent act driving the abdominal organs against the peritoneum without breaking it wide open. Such a condition would be followed by signs and symptoms, both local and general, that would be unmistakable

"Hernia is not due to traumatism or injury, but is a perfectly natural occurrence that may develop in any individual not made proof against it, or immune to it, by a perfect anatomical organism

"If he has a preformed sac, the only sure way an individual can avoid developing a hernia sometime is to die before it shows up"

Patterson<sup>84</sup> (Harrisburg, 1918), as chief of the Division of Industrial Hygiene and Engineering, Pennsylvania Department of Labor and Industry, has had unusual facilities for a broad observation of this question and has published a very able article. He has given a very interesting review showing the attitudes of various compensation boards on the question of hernia and clearly shows how foolishly different their rulings are. His own opinion is that 'hernia in practically every case (except those very rare cases where a traumatism causes a solution of continuity of the abdominal wall) is the result of a prenatal anatomical defect and should be classed as a disease and not as an accident"

Patterson considers that "all other cases will be considered as either congenital or of slow development and not compensable, being a disease rather than an accidental injury, unless conclusive proof is offered that the hernia was immediately caused by such sudden effort or severe strain that

82 Colcord Internat J S (Sept) 1919

83 Saunders, B Texas State J M 14 164-166 (Aug) 1918-1919

84 Patterson, F D Penn M J 22 633-642 (July) 1919

"1 The descent of the hernia immediately followed the cause

"2 That there was severe pain in the hernial region

"3 That there was such prostration that the employee was compelled to cease work immediately

"4 That the above symptoms were of such severity that the same were noticed by the claimant and communicated to the employer within twenty-four hours after the occurrence of the hernia

"5 That there was such physical distress that the attendance of a licensed physician was required within twenty-four hours after the occurrence of the hernia"

(The foregoing five criteria have been adopted by the Legislature of the State of New Jersey and made statute law I would add one more item which I consider to be very important, namely, that the strain or whatever force it may be must be adequate)

The physicians constituting the Conference of the Industrial Physicians and Surgeons of Pennsylvania, at the meeting addressed by Patterson, unanimously adopted his views and recommended to the state legislature a proposed law embodying them This bill, for reasons unknown, was not passed

Sellenings<sup>85</sup> (New York, 1920) "Any traumatism sufficiently severe to produce a hernia acutely should, of necessity, be accompanied by shock, but shock is conspicuously not recorded in these traumatic hernias Indeed, the claimants in these cases quite generally continue their daily pursuits until seized by the inspiration of cause and effect

"The sudden first appearance of inguinal hernia in the sense that it constitutes an accident is an impossible event The peritoneum cannot stretch instantly, but it has great power to stretch gradually Local blows cannot cause a hernia, they may cause a subcutaneous laceration

"In academic discussions of hernia, apart from the medical-legal aspect, there seems to be a uniform acceptance of the congenital origin of hernia

"Hernia is not the result of immediate sudden effort, it is always of slow formation, and very few individuals are aware of its oncoming Its development is gradual and almost painless

"A hernia is a matter of scientific fact and not one of court interpretation"

Hopkins<sup>86</sup> (Chicago, 1921) "Personally, the more we see of these cases of traumatic hernia and of so-called traumatic hernia, with the alleged ease of their acquirement, and with the absence of symptoms that should have presented at the time the hernia is said to have been received, the more firm is our conviction that the actual occurrence of true traumatic hernia, in the average individual who comes before us, is rarely, if ever, seen

"No doubt there are cases of true traumatic hernia, but in railroad surgery in particular, which calls for the care of patients who have received severe falls or squeezings through the abdomen and pelvis, producing extreme intra-abdominal pressure, sufficient to cause rupture of the bladder, kidney, liver, intestines, or to crush the pelvis, why is it that inguinal hernia is never found as a concomitant, unless the injuries were probably of sufficient severity to cause death?"

Hopkins notices that in his railway experience employees who are examined before employment present less than 1 per cent of claims for traumatic hernia Employees in classes not examined which include largely the Southern Euro-

85 Sellenings, A E New York M J 111 713-717 (April 24) 1920

86 Hopkins, C W Internat J S 34 14-19, 1921

peans, present more than 99 per cent of the claims for traumatic hernia. The first examination of 186 men showed forty-eight with either single or double hernias of long standing.

Moorhead<sup>87</sup> (New York, 1921) "Can a single act of violence cause a hernia?"

"No, unless it has caused a severing of the overlying muscular and fascial protectives.

"No single isolated act of violence causes a hernia unless the overlying parts have been lacerated.

"No single act of violence aggravates a hernia unless that violence produced intra-abdominal pressure and immediate onset of symptoms."

Burke<sup>88</sup> (Petersburg, Va., 1921) "The internal abdominal ring cannot, by any act of violence, be stretched sufficiently to permit protrusion and escape of abdominal contents, and at the same time the inguinal canal cannot be enlarged so suddenly as to allow this to descend into the scrotum. Common sense alone will tell us that the parts would be torn, with resulting hemorrhage, shock, etc., and probably death if such an accident could occur.

"No hernia was ever caused by trauma."

Black<sup>89</sup> (Spartanburg, S. C., 1921) "Traumatic hernia is so rare as to constitute a surgical curiosity, yet it does occur. It is characterized by great pain, collapse, nausea and vomiting. There is a distinct mass, exquisitely tender, which does not disappear on reclining but may be reduced by taxis, or operation."

Duncan<sup>90</sup> (Omaha, 1921) "We must always keep in mind that the particular act or circumstance to which the hernia is attributed may have only enlarged a preexisting hernia sufficiently to make it noticeable to the patient."

He reports that in six out of his own twenty-two cases of double hernia the patient was aware of hernia only on one side.

Coley, Leigh, Walker and Hopkins,<sup>91</sup> of the United States and Hutchison, of Montreal, 1922, have published the most recent, as well as the most authoritative, American contribution. These surgeons have constituted a committee on traumatic and industrial hernia for the medical section of the American Railway Association. Their report should be read in full. A few quotations, however, will serve to indicate their general attitude. "The all-important cause of hernia of all varieties is the presence of a preformed sac of peritoneum.

"Unfortunately, courts and juries and compensation laws here and abroad have not kept pace with the developments of surgery.

"Russell maintains that an acquired hernia does not exist, and recognized authorities on hernia have come to agree with Russell's conclusions.

"Hernia is practically always due, first to the presence of a preformed sac or open pouch of peritoneum which, in the inguinal variety, follows the testis in its descent into the scrotum, which pouch has failed to close in the normal way, and second, to the presence of structural weakness in the neighborhood of the hernial orifices due to poorly developed muscles or fascia. Given these

87 Moorhead S. *Clinics N. America* **1** 1573 (Dec.) 1921

88 Burke, J. M. *Internat. J. S.* (Feb.) 1921

89 Black, S. O. *South M. J.* **14** 625-629 (Aug.) 1921

90 Duncan, J. W. *Nebraska M. J.* **6** 235-243 (Aug.) 1921

91 Coley, Leigh, Walker, Hopkins & Hutchison. *Ann. Surg.* **75** 467 (April) 1922

all-important anatomical causes, which are in themselves sufficient in many cases to constitute a potential hernia, the actual hernia may develop by reason of a great variety of exciting causes, among these may be mentioned the daily increase in intra-abdominal pressure incident to the ordinary routine of life, e g, straining at stool, coughing, sneezing, lifting, etc. The main point that cannot be emphasized too strongly is that the hernia is never the result of a single strain or single increase in intra-abdominal pressure due to any of the causes mentioned, on the other hand, it is the cumulative effect of a great number of strains spread over a considerable period of time. In nearly all cases, hernia is of gradual onset, and is rarely accompanied by pain, and most frequently remains unnoticed until it has reached a considerable size or until some accident or strain, by slightly increasing the contents of the hernia sac, causes it to be noticed for the first time. Hence, the accident or strain is usually the occasion which first attracts the attention to a hernia long present but hitherto undiscovered. It has been a matter of almost daily observation at the Hospital for Ruptured and Crippled to find a patient applying for a truss or for operation for a hernia on one side, when careful examination discloses that he has a hernia on the other side, almost, if not quite, as large as that for which he applied for treatment. The size of the hernia and the character of the sac as determined by operation prove beyond question that this hernia existed for a long period and was quite unrecognized by the patient. Hence it is true that, in many cases, a person who claims that his hernia is due to an accident or any injury may sincerely believe this to be the fact, because he was unaware of the presence of a swelling prior to the accident, although it had really existed for months or years before. In all our experience we have never seen a single case in which there was any sound basis for the claim that the accident or injury was the cause of the hernia.

"Convince the commissions and the courts of the well-established surgical fact that hernia is a disease and not the result of an accident.

'Any case of hernia developing in the course of duty, incident to the man's daily work, should be treated as a disease due to special anatomical weakness on the part of the individual, for which the company is in no way responsible."

Brickner<sup>92</sup> (New York, 1922) "If those who are familiar with the anatomy of hernias stop to think of the matter, they must recognize that a fully developed hernia cannot possibly be produced by any single blow or effort causing increased intra-abdominal pressure. The accumulating literature of recent years shows that the surgeons, especially, have been thinking, and that the belief that hernias have their origin in strains and injuries is being gradually abandoned. It is interesting to note, too, in occasional reports of decisions by courts and workmen's compensation boards, that there is, correspondingly, a growing recognition of hernias as anatomical defects rather than as consequences of traumata."

#### GERMAN LITERATURE

Grasser,<sup>93</sup> 1900 "It is the consensus of opinion among those who have given the subject most careful attention that the sudden complete development of a hernia is a very rare occurrence, so rare that it is of hardly any significance from a practical standpoint."

<sup>92</sup> Brickner *Herniae and Accident Claims*, *Am J Surg* 36 148 (June) 1922

<sup>93</sup> Grasser *Handbook of Practical Surgery* 20, 1900

Golebiewski<sup>94</sup> (Berlin, 1900, translated by Bailey), quotes from the German Manual of Accident Insurance "To justify the payment of insurance, the hernia must be developed suddenly and be accompanied by intense pain

The sudden development of a hernia invariably causes pain of a character so intense as to be almost unbearable, to which the affected individual involuntarily gives expression, and which obliges him to interrupt his work and to consult a physician at once

If no proof of this kind is forthcoming, it is to be presumed that the work during the performance of which the descent of the hernia occurs furnishes the occasion of the same but does not act as its cause, and is, therefore, to be regarded as the cause leading to the discovery of the condition, not as the cause of the hernia itself"

Sultan<sup>95</sup> (Gottingen, 1902, edited by Coley) It may be emphasized that complete protrusion of the peritoneum into a hernial sac never occurs from a single augmentation of intra-abdominal tension, no matter how great it may be Such a protrusion always occurs slowly, as the result of the repeated effect of some of the influences just mentioned

"If a hernial tumor suddenly makes its appearance during a marked increase of intra-abdominal tension in an individual who has previously presented no signs of hernia, we may be sure that the hernial sac was either congenital or gradually formed during some period of extra-uterine life

'A hernia, complete in all its parts, can never arise at the moment of an accident or by a single augmentation of intra-abdominal tension, be it ever so great If the hernia appears at the time of the accident, we may certainly suppose that the hernial sac either was congenital or gradually formed in the manner already described"

Von Bergman,<sup>96</sup> 1904 The article on hernia in this system is by Grasser, who confirms the views previously quoted and says, "Only a very small percentage of hernias are the immediate result of accident The early stages of hernia are overlooked by the majority of individuals, and the patients are not aware of the condition until the hernia is perfectly evident to everybody

"About one out of every fifteen males develops a hernia In operative cases, about 30 per cent show a patent vaginal process [that is, a typical congenital type of sac (?)]"

Berner,<sup>97</sup> 1904 "A sudden development of inguinal hernia is theoretically impossible and has not been demonstrated practically"

Aderholdt and Silberstein,<sup>98</sup> 1908 "We believe that hernias due to over-exertion are to be relegated to the realm of fancy In this we are supported by so experienced a man in the line of hernias as Goertz, who believes that the only cause of traumatic hernia is an actual accident and who no longer acknowledges over-exertion while working as a cause"

Krymow,<sup>99</sup> 1910 "In the inguinal region, oblique hernias are always of natural origin, but direct hernias may be artificial"

94 Golebiewski, translated by Bailey, Pearce Diseases Caused by Accidents, 1900

95 Sultan, George Atlas and Epitome of Abdominal Hernias, edited by Coley, 1902

96 Graser in Von Bergman System of Practical Surgery, 1904

97 Berner Aerztl Sachverst-Ztg, Berlin 10 472, 1904

98 Alderholdt and Silberstein Ztschr f Orthop Chir 20 1-47 1908

99 Krymow Arch f klin Chir 91 745, 1910



Schlender,<sup>100</sup> 1910 "In every traumatic hernia, one is able to prove the existence of a bodily injury which consists of wounds, or strangulation, or both 'Accidental hernias may depend on the existence of congenital tendencies or pathological circumstances Indemnities are not necessary in these cases'"

Dreesman,<sup>101</sup> 1911 "A true hernia, i e, a hernial sac and its contents without signs of strangulation, cannot be brought about by a single injury"

Scharezky,<sup>102</sup> 1913 "Without a more or less open processus vaginalis, no protrusion of the peritoneum can take place in the region of the internal inguinal ring from which a hernial sac would eventually be formed"

Koib,<sup>103</sup> 1915 "Demands for payment of accident compensation on account of sudden exacerbation of preexisting hernias are frequently and justly refused, because any hernia is naturally liable to develop and enlarge further and because such enlargement caused by work and at work must be regarded as an occupational disease'

Schepelmann,<sup>104</sup> after describing the inguinal canal, says, "In such a canal, either a congenital or an acquired hernial sac can occur, but never because of a single trauma, only by means of long-continued pressure, except if strangulation took place"

This writer quotes from the Imperial Insurance Bureau, as follows, "Whether the first appearance of hernia under the influence of an industrial accident is liable to compensation must be accompanied by proof of (1) no previous hernia, (2) strong peritoneal inflammation, vomiting, insufferable pain, incapacity for work, eventual collapse, (3) the injured person must visit a doctor within the first three days, (4) the accident must have occurred in the performance of work unusually heavy for the injured one, and even too heavy for a healthy person"

#### IV THE PRACTICAL APPLICATION OF THE SACCULAR THEORY

The foregoing review of the medical literature as noted covers my personal review of every title bearing on this phase of herma in the French and English literature, and also of abstracts made by the American Institute of Medicine of all the Italian and German titles available in the New York libraries This has included more than 200 articles in all It is a rather convincing argument that every writer has agreed more or less in complete detail with the opinions directly quoted Not a single article was found taking issue with any of the principles, with the single exception of a brief note by Keith, a British embryologist, who differs with Russell in a minor way concerning the embryology of the femoral canal

It would seem that this review of the literature without further recapitulation should be convincing evidence that the real connection between oblique inguinal hernia and trauma, accident or the compensation laws is a very limited one Even the most skeptical should agree

100 Schlender Beitr z klin Chir 66 488, 1910

101 Dreesman Ztschr f arztl Fortbild 8 221, 1911

102 Scharezky Centralbl f Chir 40 1918, 1913

103 Koib Fortschr d med 32 1045, 1059 (July 8 and 22) 1915

104 Schepelmann Med Klin 5 911 (Aug 15) 1915

that it shows that the 4,000 cases in three years in Pennsylvania represent an absurdly grotesque situation

There can be no ground whatever for denying that a congenital sac is present in practically every case of oblique inguinal hernia, and that this is the great and efficient predisposing cause of this type of hernia, and, of its own account, without any essential exciting cause, is responsible for the natural production of most hernias. Medical opinion is unanimous on this as a scientific point. It is founded on incontrovertible evidence of dissections, operations and clinical observation.

However, from the standpoint of workmen's compensation, the issue is different. Even if a man is the carrier of a congenital sac, it is freely admitted that he may go through life without an actual hernia developing in it. When such a man can definitely establish that no hernia was present before, but that, on a certain occasion, a great and adequate force has produced an actual palpable hernial tumor, he has been changed from a man who was, to all intents, in a state of normal capacity for work, to one who now has a disability requiring a serious operation for its cure and for whom, without a cure, hard manual labor may be difficult, dangerous or impossible. A part which, though weak from birth, has not been a source of disability has now become such a source, to at least some extent. The workman is in little, if any, different situation from a man who since birth has had a vision of 20/40, good enough for work, but who as the result of an injury has had a change in vision sufficient to cause a real disability.

In regard to hernia, though, such a condition can arise only very rarely, and only under the most distinctive accompanying circumstances which manifest themselves without shadow of doubt. And here is the real crux of the whole problem. Even if the funicular process does persist into adult life, the internal ring is not a gaping opening. Indeed, really, it is not a ring at all, but it is a muscular sphincter closing tightly down on the cord. The fact that, in a particular case, a filament of delicate membrane, thinner than the thinnest tissue paper, also passes down with the cord in no way alters the physical integrity of this muscular ring which fits the structures passing through it as a bottle fits a cork. The normal unstretched ring holds this process constricted to the point of complete impermeability. For this reason, we should speak of a persistent, not a patent, funicular process. Now, for a part of the abdominal contents to be forced through the ring for the first time, tight muscle must be stretched, more probably torn, fascial and aponeurotic structures must be torn, and the force to do this must be enormous. The tearing and stretching must cause immediate, very intense and prolonged pain. There must always be decided shock or collapse. The resumption of work cannot be thought of. The man doesn't need to tell his companions that something has hap-

pened. They can see it and have to carry him away. A physician is demanded post haste. Such a picture, and such a picture only, can accompany the incident when a viscus is driven for the first time through the internal abdominal ring, preformed sac or no sac. Such a case is, of course, compensable. The five criteria of Patterson, plus the sixth, adequate force, must be present in an emphasized and unmistakable degree. For the sake of brevity, such cases will be referred to below as including the six criteria. Yet how different such a case is from the typical cases with which our compensation boards have to deal. A man while at work slips or wrenches himself, feels a pain in the groin, does not stop work, or stops only for a few minutes, tells no one, continues regularly at work the same day and thereafter. Naturally, he feels of himself where he is sore, and, at the moment, or, more often that evening or several days later, he notices a lump, and with him the question of cause and effect is settled. Very often the process of reasoning is reversed. The employee notices a lump in the groin, recalls some "strain" which occurred not too long ago to be responsible for it, and a dignified compensation board must meet to consider whether this process of reasoning has been correct.

To consider more in detail which cases of claim for hernia should be contested and which should be paid, they may be divided into

1 Hernias by direct external violence

2 Hernias of effort, Type 1 (French hernia of force). These are hernias alleged to be due to muscular effort and appearing suddenly and immediately, under adequate and convincing circumstances.

3 Hernias of effort, Type 2 (French hernia of weakness). These are hernias alleged to be due to muscular effort and appearing gradually shortly or remotely after trivial effort, and under inadequate and unconvincing circumstances.

1 *Hernias by Direct Violence*—These cases, though very rare, do occur. The external force is that caused by a more or less sharp body, like a wagon pole or a bull's horn. The application of the force must be adequate, i. e., all six criteria of the typical compensable hernia must be present, more particularly since such a force must produce considerable subcutaneous laceration of the tissues. For the latter reason, especially if there is considerable edema or subcutaneous hemorrhage, the hernial tumor may not be determined until later. Such cases, rare at best, are rarer still in inguinal hernias. Punctured wounds followed by hernia speak for themselves.

It should be remembered that

(a) Localized blows, however violent to other parts of the abdomen, never yet have produced and never will produce inguinal hernia.

(b) A widespread contusion of the abdomen may rarely cause inguinal hernia. The six criteria must be present in unusually marked degree. Rupture of abdominal viscera will almost always be present in addition. A diffuse contusion is more liable to cause diaphragmatic hernia and death than inguinal hernia and a law suit.

2 *Hernias of Effort Type I*—These are hernias alleged to be due to muscular effort and appearing suddenly and immediately, under adequate and convincing circumstances. Real cases of this kind will occasionally be met. If a man can reasonably establish that he had no hernia before a certain episode, if this episode was accompanied by a sufficient muscular effort to make possible the stretching and tearing of muscles, fascia and aponeurosis, previously intact, if the immediate results are those that any medical man or intelligent layman who has had the matter explained to him must realize would have to be, that is, if the other five criteria of Patterson are present, then a compensable hernia has been produced. In such a case, the harm can be directly laid to the accident, and, as Coley says, it is immaterial whether a previously empty preformed sac was present or not.

3 *Hernias of Effort Type II*—These are alleged to be due to muscular strain and to appear gradually, shortly or remotely after trivial effort and under inadequate and unconvincing circumstances. These persons make the greatest number of claims for compensation, and are responsible for the greatest number of contests before boards and courts. They are, however, exactly those in whom there is always a congenital sac. The hernia has been forming slowly for months or years. The process has been painless, the claimant has been quite unaware that it was going on. The most trivial muscular efforts at work, at play or at home, the ordinary physiologic functions, such as coughing, sneezing, strains at defecation or micturition, have all been helping over a long time, gradually and painlessly, to dilate the internal ring, spread open the persistent process and force intestine or omentum into the congenital sac. The hernia has, in all probability, already been present for sometime before the trivial incident calls the man's attention to his groin.

Even if the incident which the claimant alleges as the sole and final cause of his hernia has made it a little larger and more evident to himself and other laymen, it has not produced any material change and has aggravated nothing in the sense that it has created a new condition which justifies holding the employer responsible for a slightly smaller hernia which has already been present for a long time. The mere fact that a given hernia does, after a certain incident contain a little more intestine or omentum than it did before does not essentially alter its condition, does not produce a new condition which is more

disabling than it was before, and does not in any way create a new condition for which the employer should be made to pay

Another possibility is present. We know that the bulging of the preformed sac and the dilatation of the ring have been going on for sometime under the constant minor strains of daily life. The small, persistent, but empty funicular process has finally grown so that now it is an adequate hernial sac. Let us suppose that it was some incident during the course of labor which has finally pushed a piece of intestine into this now open and waiting sac. The last strain is not the cause of the man's having a hernia any more than any other of the countless strains that perhaps ever since birth have gradually been helping to produce the final result. As Moorhead has well said, it is no more logical to hold this final strain to be the cause of a hernia that has been slowly developing for months than it is to consider the last expulsive effort of a woman in labor to be the cause of another human infant's being born. The last labor pain is no more the cause of a baby than a thousand other incidents of the past nine months.

To take a second illustration. A farmer starts to chop down a tree, a crooked weakling, which is not developing properly. After a few blows of the ax, he is called away. A few days later he returns, chops a little, and is again called away, and so on for several times during the next few weeks. Finally, one day he comes, strikes one last blow, and the tree falls. The parallel to what has been happening in this class of hernia is very close—each little strain, causing an additional bulge of the preformed sac, is like each blow of the ax. But the last blow of the ax is not the cause of the tree being chopped down any more than the last effort that finally drives a palpable bit of intestine into a ready and waiting sac is the cause of a hernia. The real reason for chopping down the tree was that it was a crooked weakling. The real cause of the formation of a hernia was the existence of a congenital sac, which had been gradually enlarging through the countless strains of every day life.

A third illustration is more directly apropos. Some one has told of a young foreigner who, to avoid military service, provided himself with a stick which he at frequent intervals placed against his groin and struck with a hammer. After long perseverance, he finally produced double, direct, inguinal hernia. The last blow of the hammer was not the cause of these hernias, any more than was the first, or any of the intermediate ones. Yet, if instead of the last self-inflicted blow he could adduce an accidental blow of a hammer while at work, he would ask, and in many states receive, compensation. In other words, compensation boards would hold that it was the last blow of the hammer which did cause the hernia.

A practical phase of these slowly developing hernias is this. In persons with a persistent funicular process, very often a final complete hernia is necessarily going to occur. A hernia will come anyway, work or no work. If the hernia is actually present at birth, no outsider is expected to pay for it. If it develops during infancy or childhood, no outsider is expected to pay for it. If the final event comes in adult life, why should the employer at that particular time have to pay for it, even if the "final blow" was an incident of work?

Consideration of the Type 2 hernia may be summed up as follows

1 The six criteria of a true compensable hernia are conspicuously absent

2 In the vast majority of cases, the actual hernia has already been present and the alleged injury only calls attention to it

3 If the alleged injury really did first force viscera into the waiting sac, it has simply produced a further stage in a naturally progressing process, and has in no way created a new condition demanding compensation for the final product

4 Similarly, if an admitted hernia is made larger by a strain at work, it creates no new condition demanding compensation for the final product

5 Any result, to receive any consideration at all, must be immediately present. If a "sudden" hernia, or an enlargement of an old hernia is noticed, several days after an alleged injury, there is no proof, no evidence and even no probability that the alleged injury had anything to do with it

#### V THE REMEDY

I feel as much as any one that a person with a hernia justly caused by work should be compensated. Also I am just as glad as any one to see assistance given to disabled employees. I believe, however, that the employer should be protected from fraud. He should not be made to pay for an old hernia, and he should not be made to pay for a hernia that was not really caused by work, nor in the gradually developing hernias should he be compelled to purchase the final product because the job happens to be finished while the man is in his employ. In fairness, too, a law that involves a scientific medical question should be determined in accordance with the best scientific medical knowledge on that question. The law should be more clearly and definitely determined. The employer should know which cases he is properly liable for under the law and which cases he can handle as a matter of humane business policy.

The remedy, or at least a great improvement, should not be difficult to obtain. There are two important measures: first, better instruction of the medical profession through the distribution of such literature as

the Report of the Hernia Committee of the American Railway Association, second, an active, systematic and efficient defense of unjust cases. Part of the trouble is that we have let these cases go by the board, it was cheaper to pay than to fight. But the claims are now becoming so numerous that this is no longer the case.

The defense should be made adequate. Competent surgeons of unquestionable standing, outside the company's list, should be obtained to explain the scientific basis of hernia and why the case in question is considered to be an unjust claim.

I think that not many cases will need to be presented in this way before boards and courts will be led to take a much sounder attitude.

#### VI COLLATERAL ISSUES

1 *Strangulated Hernia*—These cases will ordinarily present little difficulty. They will generally be Type I effort hernias, and the degree of force and all six criteria will be unusually prominent. If the circumstances are straightforward, compensation should be allowed. It will, so far as right to compensation goes, make no difference whether or not a definite hernia was known to be present.

Even in these cases, one definite demand must be made, namely, the effort must be distinctly greater than that ordinarily encountered in the course of the particular kind of labor. Otherwise, it should not constitute an accident of labor. It is not sufficient that the strangulation occurs simply during labor. A clerk with a well known large hernia might develop strangulation while sitting, quietly writing. He should not be eligible to compensation. He would be, of course, if the strangulation was caused by moving a heavy desk.

Operation expenses and time lost should be met as provided by the individual law. In my own opinion, disability after any hernia operation should extend for at least three months after date of operation.

Recurrences after operation for strangulation are more common than in simple cases. If recurrence does occur and if it causes disability, it will probably be necessary to accept the later condition as due to the original strangulation.

2 *Operation Elected After Relief from Strangulation*—There is another point in connection with strangulation which arises occasionally. A case is being contested under my observation now which presents the following circumstances. A man who was known to have a hernia suffered a strangulation under circumstances that were evidently an accident of work. He was taken at once to a hospital and the strangulation was relieved by taxis. The man then, at least after a few days, was as well as ever, and the local condition was the same as it was before.

A brief temporary disability is allowable. However, the man has been so impressed by the gravity of strangulation that after complete recovery he elects to have an operation. Now, it is obvious the man has returned to the condition in which he was before the strangulation. He is perhaps even in just the same condition as when he first began to work for his present employer. It is obviously unfair that the present employer should have to pay for the operation and the subsequent disability, an operation which the man elected himself but not because the temporary strangulation made it necessary.

A French medical officer reports the case of a cavalryman who, while having great difficulty in sitting a fractious horse and having to pull hard on the lines, suddenly felt a sharp pain in the groin. He at once got off his horse and fell to the ground in great distress. The medical officer was present, reached the man at once, and found a typical strangulated hernia and reduced it at once. The man had never had a hernia before. He continued as a cavalryman for more than two years under the observation of the medical officer and never had a recurrence of the hernia, or any other reminder of the incident. This shows that a temporary strangulation is not necessarily a cause of any disability.

*3 Recurrence After Operation for Radical Cure*—The condition of the subject operated on by a competent surgeon may be interpreted in two ways. He may claim, with fairness, that the inguinal canal is as strong as it was before. Indeed, it may be stronger, because a congenital sac has been removed. On the other hand, the scar tissue after the best operations sometimes gradually yields, apparently from no extrinsic reason. With this understanding, recurrent hernias may be divided into three groups.

Group A (Hernias of Effort, Type I). If a man has remained cured after operation and develops another hernia under conditions which exhibit all six criteria, it should create a compensable condition, just as though no operation had preceded. Furthermore, compensation in such a case should be considered a *de novo* matter and should be met by the employer at the time. Under these circumstances, it should not be considered as a late result of the previous cause and should not be charged to the employer at the time of the previous accident.

This, however, is an interpretation which should work both ways, i. e., if a man has been well after a radical operation for a hernia originally compensable and suffers a recurrence under aggravated circumstances corresponding to Type I, not connected with work but in sports, for instance, he should not be allowed to refer the hernia to the compensable accident which preceded the radical operation.



Group B A man develops a hernia under circumstances justly compensable. He has a radical operation. His case is duly settled, but sometime, even years later, from a trivial cause, or from no apparent cause at all, the hernia recurs. Under these circumstances, the claimant is undoubtedly justly due compensation on account of his new condition. The operation has not really cured him, and he is in just the same situation in regard to compensation as he was before the operation.

Group C A man has had an operation for a hernia which originally was not connected with industry, definitely obvious since birth, for instance. Such a case should be judged exactly as if he had had no hernia and no operation. If recurrence takes place under typical Type I conditions, he should be compensated. The barrier which broke down might have held up for life had not an adequate force suddenly broken it down. All six criteria, however, must be present, just as when an unoperated canal is broken down for the first time. On the other hand, when an operated canal gives away gradually and under no definite force, it is quite comparable to a Type II hernia and should not be compensated.

#### VII THE EXAMINATION TO DETERMINE WHETHER THE HERNIA EXISTED BEFORE THE ALLEGED ACCIDENT

If the claimant is seen within a few hours after the alleged injury, there will generally be little difficulty in deciding whether the hernia was preexistent. As the time increases, the difficulty will increase.

*History*—If the claimant admits a previous swelling but "did not know what it was," the situation clears to an extent. The question may still arise as to whether it was aggravated.

A hereditary history will be denied. Berger in 10,000 clinic cases obtained a history of hernia in the antecedents in about 1 in 5. In claim cases, the ratio was 0 in 130. In any event, the question of heredity will have little medicolegal importance.

Searching inquiry should be made as to the possibility of hernia in childhood, and into the previous industrial history. What is the duration of the present work? Has there been a recent change from a sedentary to a laborious occupation? (Compare Turner.)

The history of the alleged injury is most important. The examining surgeon should learn first the nature of the man's usual work and usual muscular effort. He then should determine as exactly as possible the nature of the force. What was the weight? How many were carrying? Did the others let go? Was there a severe effort to maintain equilibrium after a stumble or slip? What was the attitude at the moment of the force? (Strain with the legs apart and the body bent forward is said to be most conducive to the development of hernia.)

Inquiry should next determine the immediate results. What was the character of the pain? Was it immediate? How long did it last? Were there other symptoms, vomiting, collapse, etc.? Was work interrupted and for how long? When was the swelling first noticed? What physical description does the claimant give of it?

The examining surgeon should further be furnished with whatever evidence there may be from bystanders, co-employees, and any physicians that may have seen the claimant before he did.

Thus, it will be seen that the preliminary inquiry should of itself almost determine the judgment. It should develop completely how far the six criteria of a Type I hernia are established.

*The Physical Examination*—The claimant should first be examined standing. It should be noted whether the abdominal wall is firmly muscled and well contained. There are three types of lax abdominal wall which strongly indicate a Type II hernia of weakness: first, a bilateral diffuse oval or pear-shaped bulging of the inguinal regions, second, the French abdomen "en bisac" in which there is a transverse constriction at, or just below, the umbilicus, with a general forward and downward bulging of the lower half, third, the "apron" abdomen in which the lower part of the abdomen hangs down in a fold across the anterior pelvic brim and quite hides the inguinal regions from sight from above.

Then with the patient standing, later lying down, a complete examination should be made of the hernia, the canal and the rings. Equally important is a thorough examination of the other usual hernia sites.

Among the conditions which speak definitely against a hernia due to violence or effort are other hernias, known to the patient or not, undescended testis, scars of previous hernia operations, and the forms of lax abdomen noted above.

If seen recently, after the alleged accident, the following additional points prove an old hernia: signs of a truss, lax, flaccid walls, with hernial contents irreducible because of adhesions, hard, thickened, hypertrophied omentum, large external ring, with indefinite, ill-defined edges, especially if it differs markedly in this respect from the other side. The hernia should be small. Scrotal or "large" hernias are very uncommon within a year.

If seen within a few days, the hernia should be small, not larger than a hen's egg, sometimes not reducible. If it has been reduced, it may be impossible for the claimant to reproduce it for examination. A hernia that slips back with no difficulty and reappears with equal ease after a little cough or of itself when the patient assumes the upright position is one that has an old, laxly guarded, well worn path. A ring of the type mentioned in the preceding paragraph is still more significant.

here The ring in a recent, small hernia should differ little from the ring on the other side If the differences are marked, it has taken time to produce them

The importance of the external ring in connection with almost any phase of hernia study is considerably exaggerated I believe that hernia depends entirely on the peritoneum and the structures composing the internal ring and the inguinal canal I believe the outlet of the canal has little to do with it I do not believe that a hernial protrusion ever came through an internal ring and canal, to engage an external ring, just because it happened to be large And on the other hand, if a hernial sac has been pushed through the internal ring and through the inguinal canal, I do not believe that an external ring ever stopped it from going anywhere that it wanted to go Similarly, I do not believe that of itself a large ring predisposes to a hernia, much less that it should be considered as a hernia of the first degree or a potent al hernia

In a way, I believe that the same thing is true concerning the exaggerated impulse If no definite mass can be detected and one has to be contented with speaking of various degrees of impulse, it is very doubtful whether a hernia is really there

#### VIII DIFFERENTIATION BETWEEN AN OLD AND NEW HERNIA AT THE TIME OF OPERATION

The operative findings will frequently definitely answer the question in the case of a recent hernia If several months or a year or more has elapsed since the origin of the hernia, a definite answer after operation may not be so simple It must be kept in mind that there is a great distinction between the age of the sac and the age of the actual hernia

*The Sac*—One error that is frequently made is to consider that a small, thin, nonadherent, empty sac is necessarily a recent one The fact is that this kind of sac is the typical persistent funicular process Its length depends on how far the obliterative process has been effective, but otherwise it may be as thin and delicate as it was at the time of birth It remains so if not interfered with until old age It is only the presence of hernial contents which develops thickening, adhesions and the other appearances which we ordinarily associate with an old sac The same is true in the typical fetal condition in which the covering of the completely descended testis is continuous with the abdominal peritoneum The smooth, free, delicate structures will remain so from birth to old age The changes which we ordinarily accept as indicating long standing have begun only when abdominal contents have been forced into these delicate structures and have set up irritation The longer the delicate type of sac the more certain it is to be congenital

If it is adherent to the tunica vaginalis or connected with it by a fibrous band, it is certainly a congenital sac

In the presence of this type of sac, unless there are other signs, it may be impossible to form any idea as to how long ago it first began to harbor, from time to time, some of the abdominal contents. That is, we can be quite sure that the sac is congenital, but we can form no idea as to how long ago a real hernia began

No matter whether the sac is a mere dimple at the internal ring or a complete failure of obliteration or anything between the two, there will be no pathologic changes until abdominal contents are driven in and cause irritation. For this reason, I do not think the anatomic relation of the sac to the cord and cremaster gives any indication of the age of the actual hernia. When the sac is thickened and adherent to the surrounding tissues, then we know that the hernia itself is an old one, the age depending in general on the degree of thickening. The white ring due to thickening of the sac at the internal ring is also probably the result of the irritation of hernial contents and is more marked, the older the hernia

*The Contents*—If the contents of the sac at the time of operation show no pathologic changes, they give no indication of the age of the hernia. Adherent intestines and omentum, hypertrophied chronically congested or inflamed omentum, especially if adherent down to the bottom of the sac, which itself is adherent to the tunica vaginalis, prove hernias of long standing, at least several years

One need hardly mention that the "sliding hernias," that is, those with cecum or sigmoid mesenteric attachment, and all in the sac, or with the bladder in the sac, are necessarily actual hernias from birth

*Tissues Around the Sac*—In most unusual circumstances, extravasation of blood and other signs of acute trauma will be present, and if so will probably indicate a recent real traumatic hernia

Strong aponeurotic and muscle structures making up the canals and ring may still be present long after the first appearance of a hernia, especially if it is not large, and if the contents are only occasionally "down"

Weakened atrophied muscles, with large, lax rings, especially with the pillars of the external oblique stretched and poorly identified, are secondary developments due to the long-continued stretching of large hernial contents and always indicate old hernias

Marked fatty infiltration in the muscle fibers of the conjoined tendon always indicates an old hernia

# PATHOGENIC PTOSIS OF THE RIGHT COLON\*

E P QUAIN, M D

BISMARCK, N D

The intestinal mesentery undergoes a torsion in early fetal life, during which the right colon, that is, the cecum, ascending colon and nearly half of the transverse colon travel from left to right across the duodenum and toward the right kidney. According to most of our textbooks, the normal location for the hepatic flexure is in front of the right kidney and near the right border of the liver. It is a fact, however, revealed by fluoroscopic examinations and by surgical inspections, that the hepatic flexure in many persons has failed to rotate sufficiently far to the right to become fixed by the phrenocolic ligament in the classic situation just mentioned.

For the purpose of determining the position of the hepatic flexure in healthy persons, a series of fluoroscopic examinations with barium meal were carried out by my associate, Dr V J LaRose, on twenty-five undergraduate nurses, all with normal gastro-intestinal function. The interesting findings were that more than half of them had an abnormally low right colon. In two of these young women who had never suffered from constipation or other abdominal symptoms, the hepatic flexure was very near the anterior superior spine of the ilium, and the cecum rested in the pelvis.

While many persons may go through life without serious consequences resulting from an abnormal descensus of the right colon, others are not so fortunate. Given a person with a certain degree of congenital coloptosis which does not cause any marked disturbance during childhood, and impose on this person, during early manhood or womanhood, the hard stress of physical toil, without sufficient rest, irregular dietetic and physiologic habits, poor health from any cause, repeated child-bearing (for the majority of the patients are women), and symptoms and complications are very likely to attend the ptosis.

In order that the fetal colon may rotate in a semicircle about the upper abdomen, it is necessary for it to have a fairly long mesentery. If the embryonic mesocolon fails to reach the right border of the liver, or if by some premature agglutinating process it is hampered in its rotation, then the hepatic flexure and the entire right colon assume an

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\* Read before the South Dakota State Medical Association, Huron, S D, May 18, 1922

\* The terms "colorrhaphy" "colofixation" "cecofixation," "cecopsoas" and "colopsoas," as used in this article, were employed freely by Duval (Footnote 3)

abnormally low position. When this takes place, the cecum and ascending colon retain their mesentery, and, instead of becoming agglutinated to the muscles of the back, they are permitted to hang more or less loosely on this mesentery. In many persons, it is found that the agglutination and fixation of the hepatic flexure have taken place almost normally, while the cecum and ascending colon are still freely movable on their mesentery. When there has been complete failure of hepatic flexure fixation, the entire right colon hangs from a continuation of the iliac mesentery, extending upward and fusing with that of the transverse colon, and the weight or downward pull of the entire right colon is exerted from the root of this mesentery, which is attached in close relation to the duodenum, pancreas, bile ducts and solar plexus.

It would seem that whenever Nature neglects to follow out her usual plan of fixing the colon to the right flank in early embryonic life, she makes an attempt to repair her shortcomings by introducing certain ligamentous bands to prevent or at least to limit the hypermobility. It is hard to find any better explanation for the appearance of the pericolic bands and membranes. Their development at the places and in the directions where they are aiding most effectually to affix an abnormally movable segment of the colon seems to have something purposeful in it. The evolutionary reason for these abnormal structures, as stated by Lane,<sup>1</sup> Coffey,<sup>2</sup> and others, is to me quite evident. Unfortunately, this delayed attempt at fixation is not effective, and moreover it very often leads to interference with function and the production of symptoms of various kinds and severity.

The pericolic bands or membranes of most importance in the study of coloptosis are (1) a modified phrenocolic ligament which attaches the hepatic flexure to the undersurface of the liver to the posterior peritoneum, to the kidney capsule, or to the peritoneum of the right flank, (2) a membrane from the lateral abdominal wall extending obliquely down over the ascending colon, the so-called Jackson's membrane. Its purpose is evidently to lift and fix the ascending colon and cecum when these are abnormally mobile on their mesentery. Severing this membrane causes an increased mobility and descent of the cecum. Colopexy causes it to relax. Neither of these membranes is present in those who are born with a normally fixed right colon. (3) A membrane, often multiple, running from the right half of the transverse colon and its mesentery upward, to become attached to the second portion of the duodenum, gallbladder, gastrohepatic ligament, or under-

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<sup>1</sup> Lane, W. A. *The Operative Treatment of Chronic Intestinal Stasis*, New York: Oxford University Press, 1918.

<sup>2</sup> Coffey, R. C. *Phila. M. J.* **10**, Oct. 11, 1902.

surface of the liver. In cases of midline or general visceroptosis, this supporting band is often reinforced by a second membrane formation which holds the duodenum toward the liver.

#### TYPES AND DEGREES OF THE LESION

For the successful management of a given case of coloptosis, it is necessary that we have a clear understanding not only of the congenital origin, the progress and the complications, but also of the various types and degrees of the lesion. The classification given by Duval<sup>3</sup> in his discussion of the anatomic pathology of fecal stasis in the right colon is in harmony with my own observations. He gives the following general types:

1 *Simple Mobile Cecocolon*—In this condition only the cecum and the lower segments of the ascending colon are hypermobile on a mesentery. The hepatic flexure is fixed in the normal, or nearly normal, position on the posterior abdominal wall. A pericolic membrane, varying in size, is present on the ascending colon in practically every case. The cecum is thin, distended with gas, and always contains more or less stagnant liquid feces. The symptoms resemble those of our classic conception of "chronic appendicitis."

2 *Complete Right Coloptosis*—In this condition the whole right colon hangs by a mesentery, and without direct attachment to the posterior abdominal wall. Pericolic membranes are much in evidence, but they neither fix the bowel to the back nor prevent the hypermobility. If the membranes are severed, the entire mesentery comes plainly into view. Symptoms are referred toward the epigastrium and are easily mistaken for evidence of duodenal or biliary disease. The right kidney may have become prolapsed, attached to and closely follow, the hepatic flexure.

3 *Infection of Colonic Wall*—Several degrees of colitis mucosa and parietal, as well as pericolicitis, are recognized. Duval subdivides the condition into three different types. In mucous colitis, there is an edema of the mucous membrane with areas of ecchymosis and necrosis. The lymphatic glands are large and soft. In parietal colitis, the whole bowel wall is thickened. Lymphatic involvement is evident throughout the retroperitoneal space. Inflammatory adhesions appear which in course of time cover the whole segment involved. They restrict, retract, and fix the previously hypermobile colon. The adhesions may involve the omentum, transverse colon, and other neighboring organs in the upper abdomen or pelvis. From the old retracting adhesions, as well

<sup>3</sup> Duval, P., and Roux, J. C. Arch. d. mal. de l'app. digestif 10 705, 1919-1920.

as from the absorbed products of infection, secondary disease may follow, in the gallbladder, stomach, duodenum, pancreas or kidney. Stenosis and obstruction in the colon itself frequently result from the network of fibers. Constipation is intensified and alternates with diarrhea of cecal origin. During this stage, a secondary anemia is present, with a decrease of polymorphonuclear cells and an increase in lymphocytes. The skin becomes darker than in mild hemolytic jaundice. The patient's general health, both physical and mental, is

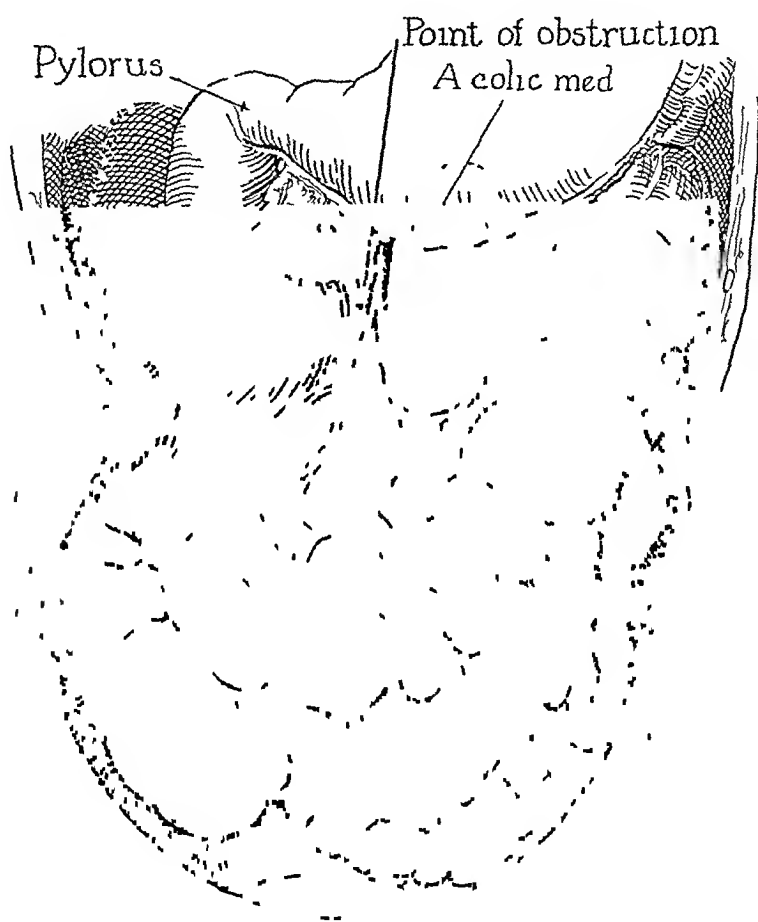


Fig 1—Right coloptosis causing obstruction of the second portion of the duodenum (from Duval)

definitely below par. An intermittent elevation of temperature is present, during which time *B coli* may be found both in the urine and in the blood.

Many conditions in a patient's life help to increase the congenital hypermobility and abnormal descent of the colon. The most active factors are the following: occupations which require standing upright during a large part of the working hours, any intervening illness which causes disappearance of fat from the body in general and



from the mesentery and retroperitoneal space in particular, frequently repeated child-bearing, by attenuating and weakening the anterior abdominal muscles, thereby giving more room for descent into the lower abdomen, insufficient food, physical and mental strains in short, every condition which tends to cause deterioration of the normal tone and human well-being

#### SYMPTOMS

Most of the symptoms induced by coloptosis are due to the dragging of the mesentery or pericolic membranes and to the constant fecal stasis. The symptoms are many and diverse, but may be grouped into three general classes: pain, constipation and intoxication.

The pain is of two types, that produced in the immediate vicinity of the colon, and that produced by dragging on other organs. The former is a chronic discomfort or pain in the right side of the abdomen, often present from childhood. It may be constant, or may be periodic. It is aggravated by occupations requiring much standing, heavy work, and foods which cause fermentation and intestinal distention. It is relieved by rest, especially when lying on the right side. It disappears temporarily after a thorough evacuation of the colon. This local pain often comes on acutely, in attacks, and may be associated with emesis and some rigidity of the abdominal wall. But the attack is never very severe, and it passes away gradually in a day or so. There is rarely any elevation of temperature, and leukocytosis is absent. A diagnosis of appendicitis is usually made, and the appendix is not infrequently removed either in one of the acute attacks, or, more frequently, on a supposition that chronic appendicitis causes the pain. Appendectomy relieves the symptoms by the enforcement of a week or two of absolute rest, and by the dietetic and occupational care which is taken for a time following the operation, but after the patient resumes his usual mode of living, the old symptoms recur in most cases.

Pain is produced at a distance, by the dragging on the mesentery. In those instances in which the mesentery at the hepatic flexure has become more or less attached to the right kidney, but is otherwise free the kidney is liable to become dislodged and displaced downward with the colon. Pain and other symptoms due to the kidney ptosis are then invoked.

When the entire right colon is free and hanging by its mesentery traction is exerted across the second and third portions of the duodenum. The pulling effect is emphasized by the firmly fixed position of the middle colic artery running within the mesentery, and by the supracolic membranes which have been mentioned. The variety of symptoms that may be produced in the gallbladder, duodenum and stomach is enough to cause serious confusion in the diagnosis of cholecystitis and

duodenal or gastric ulcer. The success of treatment, medical or surgical, directed to these organs will depend in no small measure on the recognition and management of this pathologic factor.

The pericolic membranes are very important agents in causing pain, as well as other symptoms. The membrane producing pain most fre-

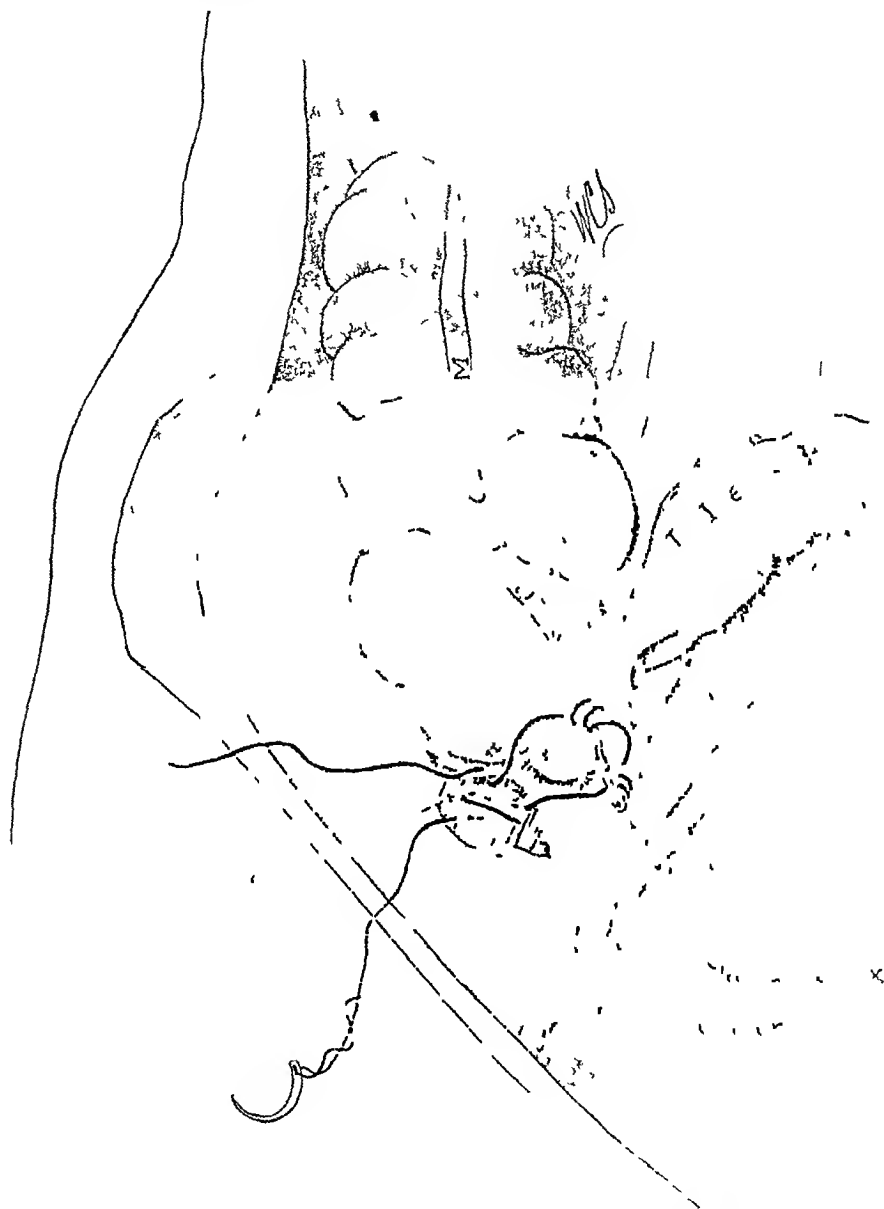


Fig 2—Method of fixation of hypermobile cecum after appendectomy

quently is, perhaps, the one located on the outer surface of the ascending colon. I have found it only in the presence of a mesocolon. When this membrane is attached to the parietal peritoneum over a very small area, it is capable of causing quite acute pain. After colofixation, which takes the tension off the membrane, the pain disappears.

The smaller the sensitive peritoneal area involved in a membrane or adhesion, the more severe the the pain. Wide and extensive adhesions cause less discomfort because the dragging effect is distributed over many, instead of a few, nerve endings.

Constipation is an early and persistent symptom of coloptosis. It should be differentiated into two types, that due to a retardation in the left colon and that due to stasis in the right. The former does not, as a rule, cause very serious consequences. The drying fecal masses contain almost no living bacteria or toxins, and many persons live in good health with very infrequent evacuations. Constipation due to delay in the right colon is much more harmful. Cecal contents are always liquid, and contain innumerable bacteria, some of which are pathogenic. Incompletely digested and absorbed food products are always present in the cecum to feed the bacteria and to produce a continuous supply of toxins. In the course of time, the cecal wall becomes more and more distended and atonic and never evacuates except from overflow. The mucous membrane loses its protecting function, and toxins and even bacteria enter and find their way to the lymphatics and thence to the general circulation. An albuminous exudate demonstrated in the feces indicates a serious degeneration of the mucous membrane. Some patients are liable to have spells of diarrhea alternating with constipation, which means that the left colon is sensitive to the irritating overflow from the right. In others the left colon may have learned to absorb the water from the overflow and to exercise regular defecation, thus helping to conceal the functional changes of the right.

Intoxication, or absorption of pathogenic products from the fallen paralytic and helpless cecum, causes a lymphangitis and lymphadenitis in the mesocolon. The enlarged lymph glands are clustered along the blood vessels. Even lymph nodes in more distant regions, near the aorta, may be affected. The local infection travels through the bowel wall, and then the peritoneum reacts by establishing a new set of membranes, inflammatory adhesions. The effect of these adhesions, often in combination with the evolutionary membranes, is to produce various degrees of obstruction to the passage of the intestinal contents. Absorption of toxins lays a foundation for a long list of constitutional symptoms, including dizziness, headaches, nausea, malaise, asthema, mental depression, and in some instances chronic mental disease.

It is possible to form a fairly true estimate as to the location of the cecum and hepatic flexure by inspection, palpation and percussion. In patients with thin abdominal walls, the fingers can easily make out a cecum mobile in its changing situations, depending on the posture of the body. However, no semblance of guesswork needs to be entertained.

in making a diagnosis, since the roentgen ray enables one to visualize exactly the conditions. By means of fluoroscopic examination we can determine the position of the colon as well as the other parts of the gastro-intestinal tract, the presence and location of stasis, dilatations and obstructions, and the degree of mobility of the organs. I shall not attempt to discuss the various forms of roentgen-ray technic required to obtain the fullest amount of information.

#### TREATMENT

The success of treatment for well marked coloptosis will be proportionate to the intelligence and cooperation rendered by the patient. In the medical treatment of the disease, it is almost impossible to obtain any satisfactory results in those who are too ignorant to grasp the meaning of the various requirements. In the care of the surgical patients, it is necessary that instructions be followed understandingly for a certain length of time after operation, depending on the patient's age. The younger the patient subjected to colofixation, the more certain and rapid is the cure.

It is, therefore, best that all patients at first be given a course of medical treatment, partly because some of the milder cases will be much improved, and partly because all the patients need to learn in detail how to manage their own conditions, or to keep up postoperative treatment. For best results, it is required that the patient go to bed in a hospital for two or more weeks. The patient is placed in the Trendelenburg position, on an incline of at least 30 degrees. This is maintained with intervals of rest for several hours each day. It is kept up for an hour after each meal. So far as possible, the patient should not raise his shoulders from the bed at any time. An enema is given at least once a day, and on the bedpan. Meats and albuminous foods are avoided. The diet is made up chiefly of vegetables, carbohydrates and fruits. This is to retard the putrefactive bacteria and to aid the fermentative flora in the cecum. Lactose in liberal amounts is of definite value for this purpose, since it passes almost unchanged through the small intestine.

The Trendelenburg posture gives the patient several distinct benefits. All the viscera, including the ptotic colon, sink toward the epigastrium, making a movement opposite to that which produced the symptoms. The right colon empties itself more easily. Visceral circulation is restored to areas which have been indifferently supplied with blood when the patient is in the erect posture. The dragging on the duodenum, stomach and bile ducts is relieved. The pulling and irritation on the solar plexus and sympathetic nervous system are removed. The relief from sympathetic nerve irritation is a circumstance which I believe to

be of very great importance. It is my belief that this is a greater factor in producing neurasthemia in those who have visceroptosis than is the absorption of intestinal toxins.

It is interesting to watch the favorable progress in a patient who has suffered definite symptoms from coloptosis after from two to four weeks of this treatment. The abdominal pain and distress are relieved or gone. Bowel movements are obtained more easily. The nervous and mental tension has given place to a feeling of rest and well-being. Symptoms of toxemia have disappeared. The appetite is improved, the blood findings approach normal, and the body weight increases several pounds.

The next problem is to prevent the colon from resuming its original malposition when the patient is allowed to leave the bed. For this purpose, a binder or corset, with a pad, is so adjusted that the lower abdominal cavity will become reduced in size and thus have less space into which to invite the ptotic organs by gravity. That a pad properly made and applied can do this effectively is proved by many patients who have learned that they become uncomfortable whenever they try to go without it. On leaving the hospital, the patients are instructed to lie down in the Trendelenburg posture for at least twenty minutes after each meal. This posture must be used after retiring and before applying the pad each time. They are also taught how to make use of the knee-chest posture if the other, more cumbersome, position is impracticable at any time. This position may also be used after going to bed at night and while putting on the pad and binder.

While many patients learn to carry on their daily work in comfort by the method described, the majority are improved only temporarily while under medical regimen. For more lasting relief, it is necessary to resort to surgery. By keeping in mind the gradations of pathologic anatomy, the indications for the various types of operation become fairly well defined. When the colonic wall has become infected and thickened and pronounced lymphadenitis and multiple adhesions are present, no operation short of right colectomy will cure the patient. Right colectomy should not be considered too formidable a procedure for these patients, in view of what it has to offer. With proper technic, the operative risk is very small.

In the presence of cecum mobile of mild degree, a fixation of the caput coli to the root of the meso-appendix should always be performed after appendectomy. It is my conviction that this fixation of the cecum, incidental, accidental, or intentional, has much more to do with the relief from symptoms after operation for so-called chronic appendicitis than the removal of the appendix itself. It is also my firm conviction that if a cecum mobile is present and not fixed when the appendix is

removed for so-called chronic appendicitis, the symptoms of chronic appendicitis will recur within a few weeks after the operation

When the cecum and ascending colon are both ptotic and hypermobile on a mesentery, a more radical fixation to the psoas muscle is made. An incision is made through the posterior peritoneum, opposite

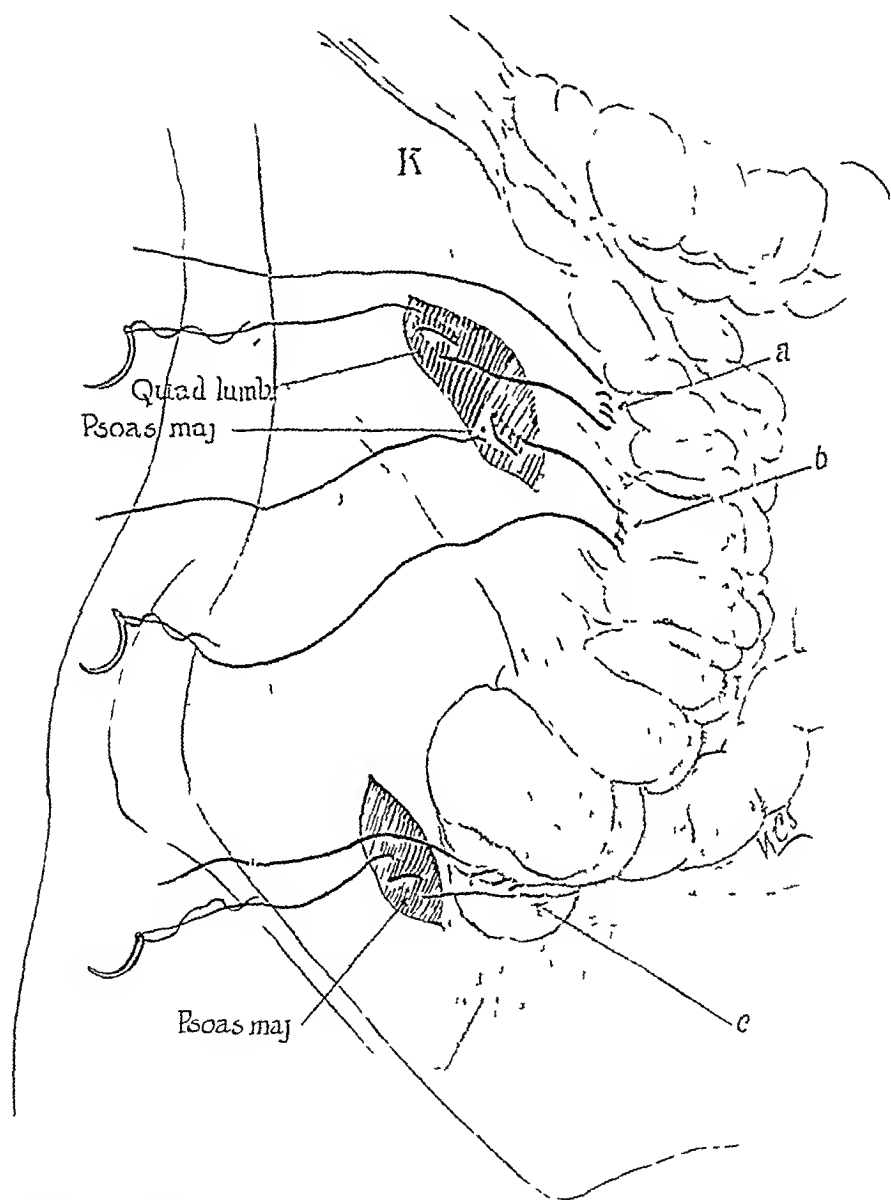


Fig 3—Methods of colofixation cecum to psoas minor, colon to psoas major and colon to quadratus

the normal location for the cecum, and the cecum is sutured to the muscle with two or three sutures of chromic catgut. When a psoas minor muscle is present, which is the case in about one half of the patients, then the sutures should include it.

When most of the ascending colon is free and involved in the hypermobility, a second peritoneal incision is made somewhat higher, over the edge of the psoas, and two other chromic catgut sutures are introduced. A very solid fixation is obtained by placing the sutures into the posterior longitudinal line of the colon, but this is likely to cause considerable backache in the first few weeks after operation and may involve a risk of too firm a fixation in some cases. All that is necessary is to pass the needle through the subperitoneal tissues at the margin of the mesocolon. It will do no harm if some of the smaller blood vessels to the colon are included in the suture. They add firmness to the fixation. It need not be stated that care must be exercised in order to avoid damaging the larger arterioles. The bowel mucosa must not be pricked with the needle, or infection is certain to follow the operation.

When there is a complete right coloptosis, a still higher fixation should be made at a point representing the hepatic flexure. It is not possible to do this to the back muscles because the kidney, with its blood vessels, and the ureter are in the way. My practice is to open the posterior peritoneum and pass two or three sutures through the areolar tissue in front of the kidney. If there is only a small amount of fat present, the muscles near the twelfth rib are easily reached at this point. If there is an abundance of fat, it has seemed best not to pass these sutures deeply under the peritoneum but to be satisfied with a broad peritoneal attachment under the liver.

When the right kidney is definitely prolapsed with the colon the fatty capsule is split over the dorsum and peeled loose from the kidney. The tuft of fat thus freed externally, but attached in front of the kidney pelvis, is gathered together with two or three sutures of chromic catgut and sutured firmly to the quadratus lumborum. This forms a shelf on which the kidney rests, and is a much better procedure than all attempts to anchor the kidney itself. The shelf blocks the way for all future chances of recurrence of the kidney ptosis. When this technic for kidney fixation is called for, the colon is sutured into the newly made kidney shelf. A rubber cigaret drain provides an outlet for the inevitable oozing which will follow the kidney operation.

Approaches to the fields of operation are obtained either through a double split-muscle incision or through a transverse opening of the abdominal wall. I<sup>4</sup> have previously described the principles and technic of these incisions.

After the adoption of the technic of colofixation, as described above, the results obtained from the surgical treatment of coloptosis have been very satisfactory in my experience. Since my attention was

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4 Quain, E. P. Abdominal Incisions, *Arch Surg* 1 585 (Nov.) 1920

first attracted to visceroptosis, about twelve years ago, several methods of surgical treatment for coloptosis have been tried out

Suspension of the transverse colon to the anterior abdominal wall, as recommended by Rovsing, Coffey, and others, did not prove satisfactory for the treatment of this type of ptosis, although the method undoubtedly is of distinct service in certain midline ptoses of an

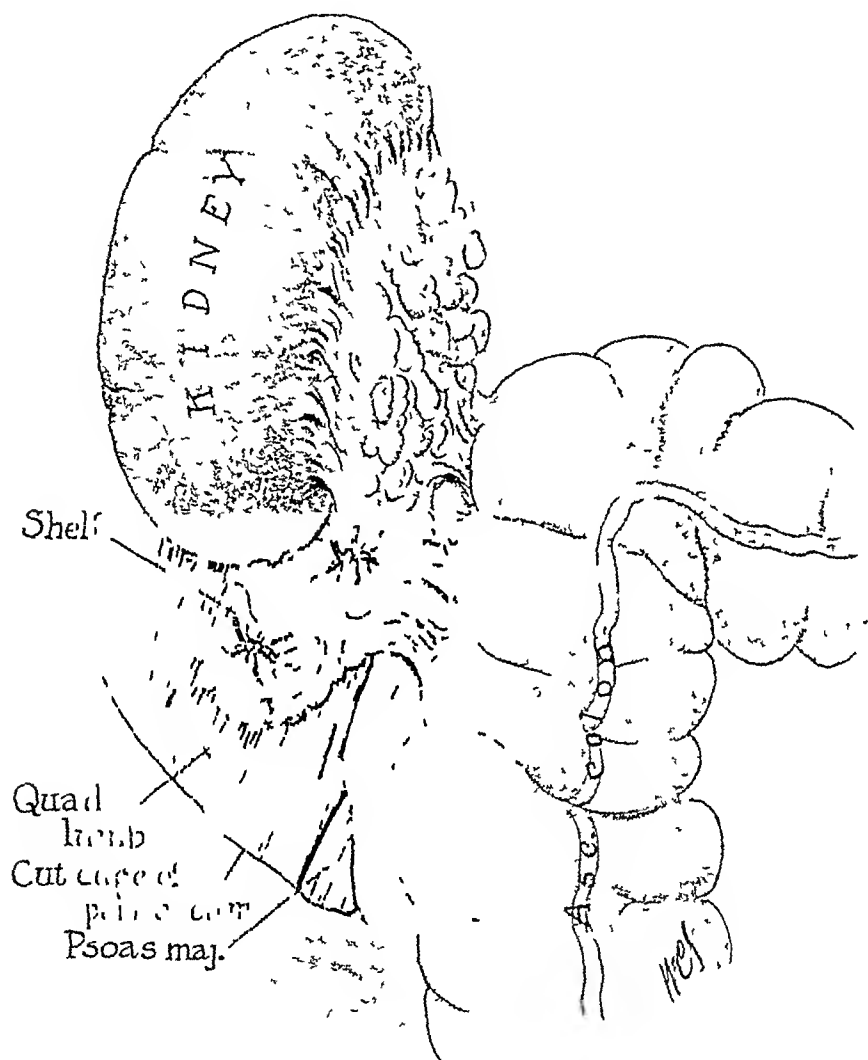


Fig 4—Kidney shelf made from fatty capsule

acquired nature. In some patients, new symptoms developed after operation, such as epigastric pain and interference with gastric and colonic functions. Moreover, it gave no relief to a ptotic cecum. Various types of colorrhaphy and peritoneal "pexies" were also employed. From these the best results were obtained by shortening the longitudinal



bands of the ascending colon, provided the sutures were so placed that the weight of the cecum was transferred from a pain-producing pericolic membrane to the ascending colon above the membrane. Suturing of the cecum or its mesentery to the posterior peritoneum externally to the colon, while both pain and constipation might be temporarily relieved, was almost invariably followed by recurrence of cecoptosis and symptoms. I have operated on a number of patients after previous colicrhapsies, and from the findings at operation it was evident that a ptotic colon will in the course of time overcome and undo any attempt at fixation which is based on peritoneoperitoneal adhesions.

Eleven colectomies, eight of the right colon, and three total excisions, have been made because of colitis due to ptosis and stasis. The only patient who died after operation for coloptosis was one in whom a septic retroperitoneal infection began a few days after operation, a right colectomy. This was a tragic lesson teaching the danger of opening lymphatics behind an infected colon without proper provision for drainage. One patient who suffered from melancholia before the operation was not improved mentally, although the abdominal symptoms were evidently much improved. One patient suffered a severe attack of influenza and bronchopneumonia immediately after operation and was treated for fecal fistula and bronchial infection for three months. The patient was then discharged cured. The remaining eight are practically well.

The technic of incision through the posterior peritoneum and fixation directly to the muscles of the back has, up to date, been employed on more than seventy patients. Personal reexaminations and answers to letters of inquiry have given postoperative information from fifty-two of those who were operated on three months ago or more. It should be stated that the syndromes of these varied in severity from those that we formerly associated with chronic appendicitis and constipation to more aggravated forms of renal, biliary, and duodenal complications. Cecopsoas or colopsoas fixation for simple mobile cecocolon was made in thirty-six of the fifty-two patients. Fixation of the entire right colon was accomplished in the other sixteen. Because of complications from coloptosis, nine nephropexies, five duodeno-jejunosomies, and four cholecystectomies were performed, in conjunction with colofixation. Eleven patients had submitted to previous unsuccessful operation, or operations, for the cure of chronic appendicitis, cholecystitis, and duodenal ulcer.

The following is a brief summary of the results following colofixation. Twenty-two, or 61 per cent, of the thirty-six who had cecopsoas and colopsoas fixation are free from all previous symptoms, and twelve, or 75 per cent, of the sixteen with complete colofixation are

symptom-free. The majority of the remainder, about one third of the total number, named constipation as the symptom which had not been entirely overcome by the operation. Four complained of occasional backache, and three had some colicky abdominal pains. More or less relief from previous symptoms was acknowledged by all but three, who stated frankly that they had received no benefit from the operation. Not the least satisfactory were the results in those patients who were relieved of symptoms in other organs, the kidney, gallbladder, and duodenum, and in whom the most radical and multiple interventions were undertaken.

It will be noted that the lowest percentage of cures was found after the more simple surgical procedures. It was natural that the surgeon, traveling on a poorly blazed surgical path, in the beginning of this method of treatment, should hesitate before employing the more radical technic, and the result was that many patients did not receive surgical treatment in proportion to the degree of the lesion. In the light of more experience, I know that failure to excise an infected or paralyzed colonic segment has been the cause of persisting constipation and other symptoms in several patients. It is improbable that a chronically over-distended and atonic cecum can regain its tone and function from any change in its position. Microscopic sections made from the stretched out longitudinal bands of such a cecum show degeneration of muscle fibers, even in the absence of gross evidence of bowel wall infection.

It must be admitted that sufficient time has not elapsed to permit one to make any assertion as to the permanency of cure following colofixation by the method described. However, a number of patients formerly chronically ill, who have been free from previous symptoms and capable of a full enjoyment of work and play during more than two years following the operation have given an assurance which amply justifies confidence for the future and a continued application of the treatment.

#### CONCLUSIONS

- 1 Coloptosis is a very common anatomic abnormality.
- 2 Comparatively few of those who have a ptotic colon suffer serious symptoms as a consequence, but the incidence is, nevertheless, much greater than we formerly supposed.
- 3 Some of the effects of coloptosis are translated to other abdominal organs which may then give rise to a new set of symptoms, thus obscuring the original and chief cause of the trouble.
- 4 Medical treatment gives relief in most cases and should be given a thorough trial in all cases, but its ability to cure is doubtful in any case.

5 Surgical treatment is as successful in these lesions as in many other so-called surgical diseases and promises better results as experience accumulates

6 Chronic appendicitis is an infrequent disease, and the term should be restricted to those comparatively few instances in which there actually is a chronic lesion of the appendix

# CARCINOMA OF THE APPENDIX<sup>1</sup>

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Although carcinoma of the appendix is no longer considered a rare disease, the condition may easily be overlooked unless a careful routine examination is made of all appendices removed. The surgeon often sees an obliterated, or partially obliterated, rather harmless appearing appendix, and he is in doubt as to the advisability of its removal. It has been shown that one in every fifty-three of such appendices is carcinomatous.

In 1911 MacCarty and McGrath<sup>1</sup> reported from the Mayo Clinic the results of the study of 5,000 appendices and demonstrated that one of every 225 was carcinomatous. In a later series, they found eighteen (0.6 per cent) of 3,039 specimens to be carcinomatous.

With a view to determining the prognosis, the forty cases reported by MacCarty and McGrath have been followed, also twenty-four<sup>2</sup> later cases in which specimens had been studied microscopically.

In ninety cases of primary carcinoma of the appendix collected from the literature by McWilliams<sup>3</sup> in 1908, seven patients were alive and well after five years, thirteen after three years, and twenty-one after two years. Kelly<sup>4</sup> reported a case in which the patient had been in poor health for nine years. He had had constant sharp pain in the right iliac fossa and tenderness in the incision. In 1915, Meyer<sup>5</sup> reviewed the literature to date, compiling the reports of 269 cases,

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\*This study was made in the Section on Surgical Pathology under the supervision of Dr William C MacCarty.

1 MacCarty, W C, and McGrath, B F. Clinical and Pathological Significance of Obliteration, Carcinoma, and Diverticulum of the Appendix, Surg, Gynec & Obst **12** 211-220, 1911.

2 MacCarty, W C, and McGrath, B F. The Frequency of Carcinoma of the Appendix, Ann Surg **59** 675-678, 1914.

3 McWilliams, C A. Primary Carcinoma of the Vermiform Appendix. A Study of Ninety Cases, Three Previously Unpublished, Am J M Sc, **135** 822-850 1908.

4 Kelly, A O J. Primary Carcinoma and Endothelioma of the Vermiform Appendix. Am J M Sc **135** 851-856, 1908.

5 Meyer, L B. Primary Carcinoma of the Appendix. A Review of the Literature, with a Report of Three Additional Cases, Surg, Gynec & Obst **21** 354-360 1915.

including three of his own. Since then I have found reports of twenty-four cases including twelve by Reimann<sup>6</sup>. These, with the twenty-four here reported, bring the total to 317 cases.

#### PROGNOSIS

Thirty-seven of the sixty-four patients observed in the clinic were traced. Two had died from accident or of conditions in no way related to the disease and two had died of postoperative complications. The remaining thirty-three are living and, in most instances, well (Table 1).

Operation resulted in cure of the malignant condition in 100 per cent of the patients traced. Carcinoma of the appendix, then, assures the most favorable prognosis of all forms of malignancy of the gastrointestinal tract as indicated by this percentage of cures. It is significant, however, that the surgeons had not made a positive diagnosis of malignancy in any cases in the first two series reported by MacCarty

TABLE 1—PROGNOSIS IN THIRTY-THREE CASES OF CARCINOMA OF THE APPENDIX

Cases	Years Since Operation	Cases	Years Since Operation
1	16	1	7
1	15	2	6
1	13	1	5
5	12	2	4
4	10	3	3
3	9	3	2
3	8	3	1

and McGrath. In only five of the twenty-four cases here reported was a positive surgical diagnosis of carcinoma made, although the lesion was suspected in four other cases.

Although this report is confined to cases of primary carcinoma of the appendix, a number of cases were reviewed in which carcinoma was present in both the appendix and cecum, suggesting a relationship between the two. Pathologists disagree on the possibility of carcinoma of the large bowel originating in the appendix, but until the point is more definitely settled, such a possibility must be considered.

#### CLINICAL SIGNS

There is little of significance in the clinical history of these cases. Sixteen of the twenty-four patients observed since 1911 were females, eight were males. The average age of the women was 42 years, of the

<sup>6</sup> Reimann, S. P. Primary Carcinoma of the Vermiform Appendix, *Am J M Sc* **156** 190-201 (Aug) 1918.

men 40. Twelve gave a history of previous trouble in the appendix, twelve gave histories of other symptoms. The average duration of symptoms of appendicitis was six and eight-tenths years.

The facts of value in these data are that 50 per cent of the patients gave a history of previous trouble and that the disease is seen twice as often in women as in men. These findings are in accord with those of other observers.

McWilliams reported that 83 per cent of seventy-six patients gave a history of previous trouble in the appendix. In forty-seven of seventy-eight cases, the condition was present before the age of 30. He remarked that in 60 per cent of the cases, malignancy before the

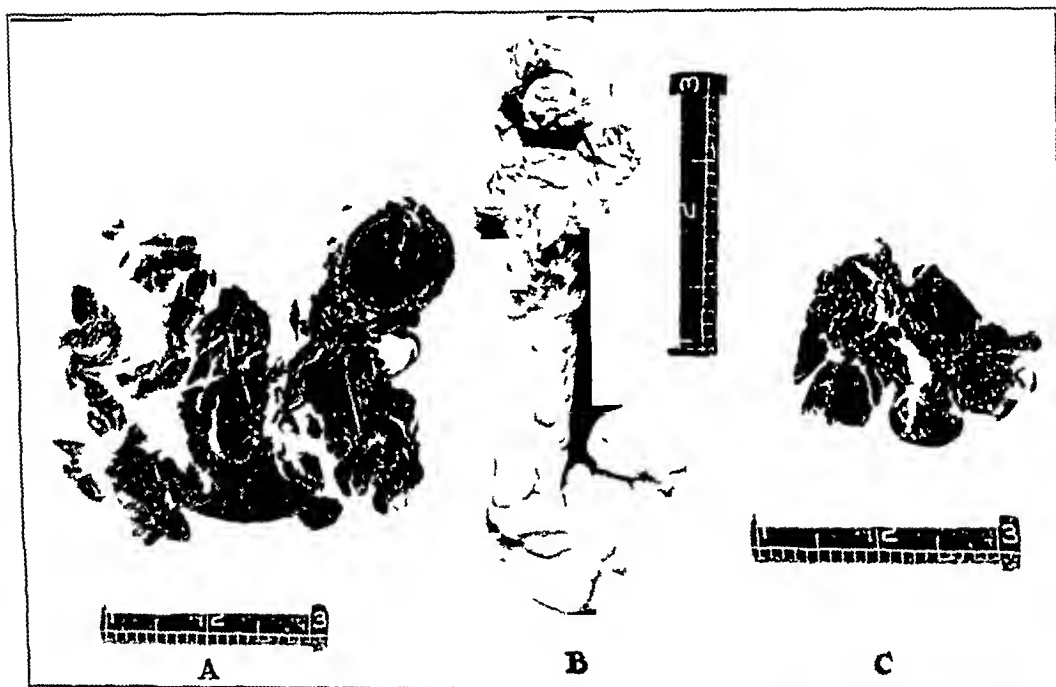


Fig 1—*A*, cross-section of obliterated tip of appendix showing carcinoma, *B*, extensive involvement of the base of the appendix by carcinoma, *C*, specimen of a colloid carcinoma involving the tip of the appendix.

age of 30 is in marked contrast to the age incidence in malignant tumors of the remainder of the intestinal tract. Rolleston<sup>7</sup> reported 180 cases of carcinoma of the intestinal tract, exclusive of the appendix, with an average age of 49 years, these patients were twenty years older than the patients with carcinoma of the appendix.

Deaver, in an analysis of 3,000 cases of simple appendicitis, showed that 69 per cent occurred in patients before the age of 30,

<sup>7</sup> Rolleston, H. D., and Jones, L. Primary Malignant Disease of the Vermiform Appendix, *Tr. Med. Chir.* 89: 125-153, 1906.

and that 38 per cent of the patients were females and 62 per cent males. No explanation has been offered for the complete reversal in frequency of the two conditions in the two sexes.

A history of previous trouble in the appendix in 50 per cent of the Mayo Clinic series is in accord with the pathologic findings, the lumen is usually found obliterated, indicating a previous inflammatory lesion. This is an important surgical point, and shows that in every case with a history of trouble in the appendix this process should, if possible, be examined carefully for signs of malignancy. Since surgeons have learned to recognize this condition more readily, they have been more careful to remove all appendixes in which there is a suggestion of malignancy. One result has been the discovery of many malignant appendixes that might otherwise have remained undisturbed.

#### TYPES OF TUMORS

Considerable doubt exists concerning the pathology of these tumors. Mallory<sup>8</sup> says: "It is difficult to decide the exact nature of certain small tumor-like collections of epithelial cells occurring occasionally in the appendix, but also more rarely in the small intestine. They resemble a carcinoma in structure and are found most often in young persons. The cells are small, are grouped in solid masses, and may occur not only in the mucosa but also in the muscle coats and subserosa. In the appendix they often look as if they had started from the mucosa and more or less completely destroyed it, and then infiltrated the surrounding muscle and fibrous tissue. On the other hand, they show little or no activity of growth and there is no evidence of reaction on the part of the tissue around them. They are regarded by some as a local tissue abnormality comparable to the congenital nevi of the skin."

In 59 per cent of seventy-one cases reviewed by McWilliams, the carcinoma occurred at or near the tip, and in 33 per cent no tumor was visible to the naked eye. In twenty-three of forty-two cases, or 55 per cent, one or more solid tumors were visible.

In the Mayo Clinic series of twenty-four cases, the carcinoma was located at the tip in twenty-one, at the base in two, and at the middle in one.

The tumor in situ grossly resembles concretions within the lumen. On transverse section the lumen is seen to be obliterated by a solid growth which is homogeneous and fibrous in appearance and presents an orange color in specimens preserved in liquor formaldehydi.

Certain observers, such as Neugebauer, have classified the majority of tumors of the appendix as endotheliomas, partly on account of the type of cell, and partly on account of the benign nature of the tumor.

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<sup>8</sup> Mallory, F. B. *The Principles of Pathologic Histology*, Philadelphia, W. B. Saunders Company, 1914, p. 389.

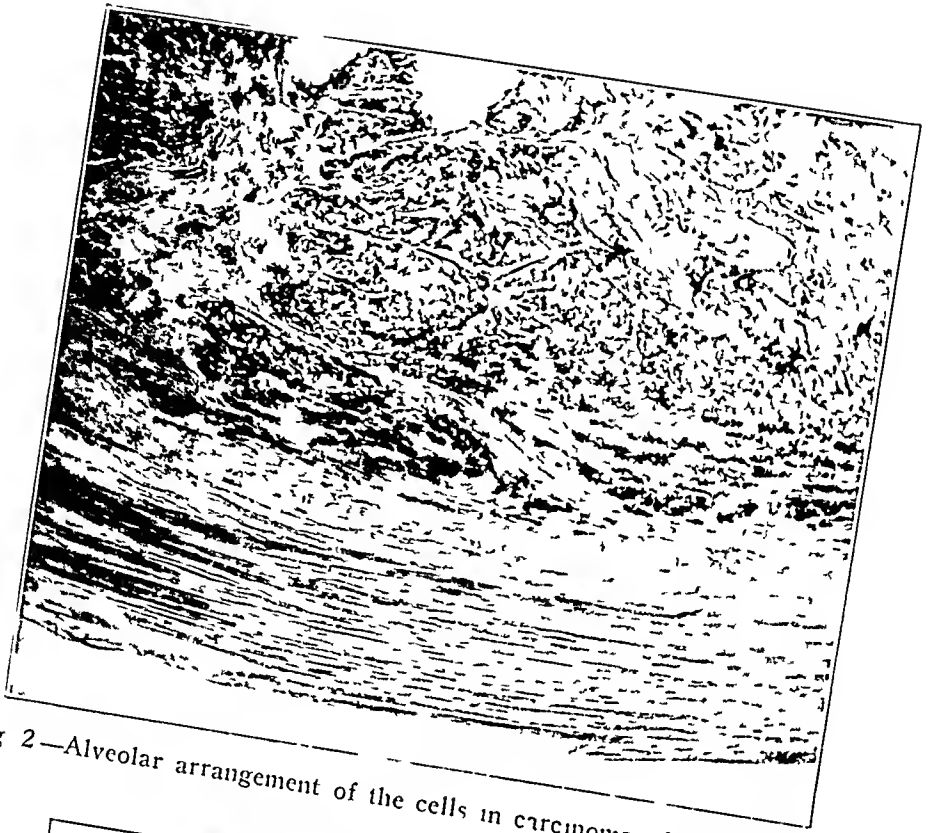


Fig 2—Alveolar arrangement of the cells in carcinoma of the appendix

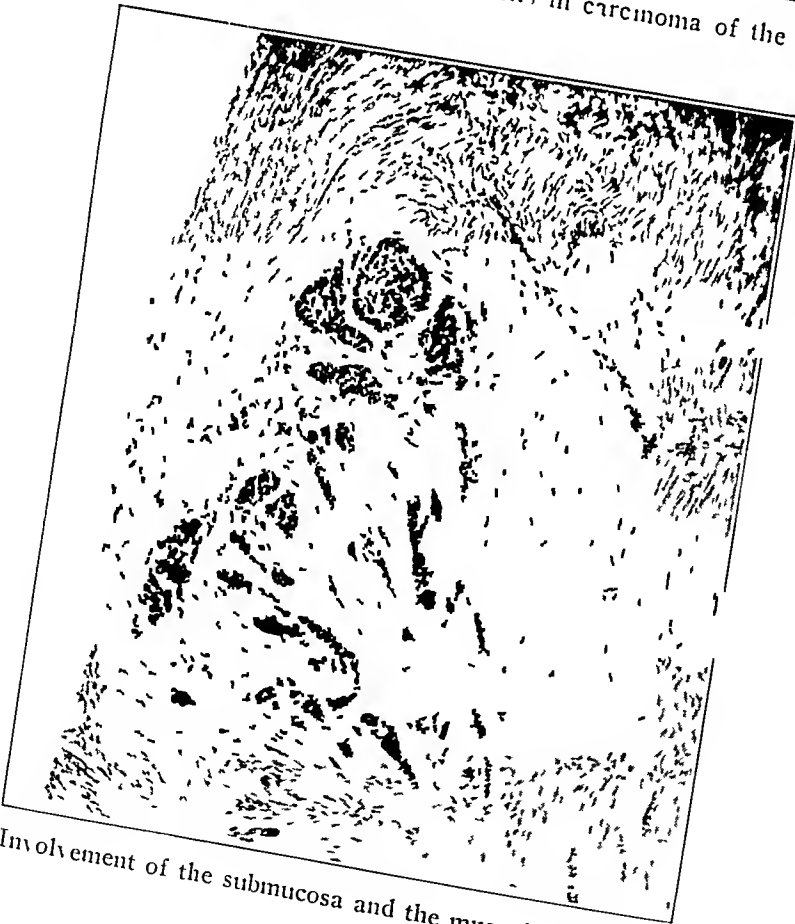


Fig 3—Involvement of the submucosa and the musculature by carcinoma



Graham in a review of 172 cases reported in the literature up to 1908 divided carcinoma of the appendix into two main groups, the spheroidal cell and adenocarcinoma. The spheroidal cell carcinoma has been described as scirrhous, medullary, simple, alveolar and basal, but the detailed descriptions indicate that the cases recorded under various names are practically identical. This type occurs in 73.8 per cent of cases. The second type, adenocarcinoma, includes cases described as cylindric-cell carcinoma and colloid adenocarcinoma. This type includes 18 per cent. Five and eight-tenths per cent of the cases not included in either group are recorded as transitional, between spheroidal-cell and adenocarcinoma, 2.3 per cent of the cases are called colloid carcinoma. The average age in cases of adenocarcinoma and of colloid carcinoma is somewhat greater than that in cases of spheroidal carcinoma, it corresponds more closely to the age at which carcinoma of similar type occurs in the large intestine.

There is a further difference between the two types in the degree of malignancy, as was pointed out by Rolleston and Jones. In only one

TABLE 2—AVERAGE AGE IN CASES OF VARIOUS TYPES OF TUMOR

Type	Cases	Average Age
Spheroidal	127	27.2
Adenocarcinoma	31	39.5
Transitional	10	29.8
Colloid	4	44.7

case of the spheroidal-cell type, in which the growth was undoubtedly primary in the appendix, was there invasion of the cecum or spread by metastasis. In six of thirty-five patients with adenocarcinoma or colloid carcinoma, however, carcinoma spread to the cecum or to the abdominal glands by metastasis. The average age in these patients was 51.8 years. Recognition of the difference in the degree of malignancy of the two types is important, since the prognosis must be guarded when adenocarcinoma or colloid carcinoma occurs, especially in middle-aged patients.<sup>9</sup>

The microscopic examination reveals irregular masses of epithelial cells closely packed in alveoli, surrounded by a heavy fibrous stroma. Although all the coats are invaded, the growth is chiefly confined to the mucous and submucous layers. The protoplasm of the cells is pale and scanty, but the nuclei stain darkly. MacCarty describes the nuclei as generally oval or round, with fewer irregularities than are presented by carcinomatous cells in other portions of the alimentary tract.

<sup>9</sup> Graham, J. M. Primary Cancer of the Vermiform Appendix, *Edinburgh M. J.* 10: 30-41, 1913.



Fig 4—Involvement of all the coats of the appendix by carcinoma

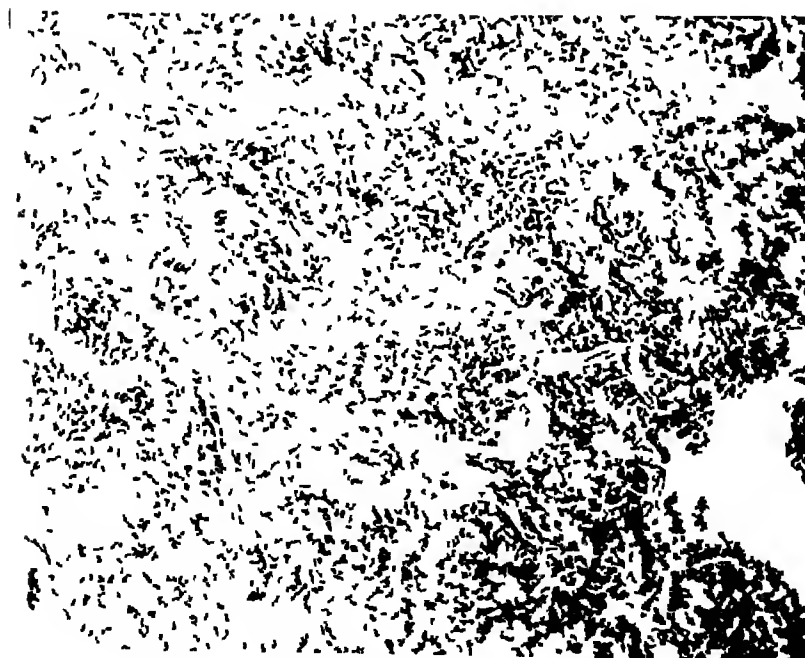


Fig 5—Irregular masses of epithelial cells closely packed in alveoli

In this series of sixty-four cases, one specimen was diagnosed colloid carcinoma, the remainder may be classified in the so-called spheroidal group. Adenocarcinoma was not found.

The influence of chronic appendicitis as a factor in the production of carcinoma is evident from the appearance of the lumen and the number of twists and kinks in the region of the tumor. Graham states that it seems justifiable to conclude that in a certain number of cases the exciting cause of carcinoma may be found in the irritation of isolated tubules or of mucosa undergoing the process of obliteration. The effects of chronic lesions are evident in the production of gastric cancer and the same factors are probably effective in carcinoma of the appendix.

#### CONCLUSIONS

1 The prognosis following early removal of carcinoma of the appendix is more favorable than that for malignancy in any other part of the gastro-intestinal tract.

2 The appendix should be examined carefully in every laparotomy when possible and should be removed if any abnormality is present.

3 A preoperative diagnosis of carcinoma of the appendix is impossible because of the absence of distinguishing clinical signs.

4 A definite relationship exists between carcinoma of the appendix and chronic appendicitis. Obliterated appendixes should be carefully examined for signs of malignancy.

5 The relationship of cecal carcinoma to carcinoma of the appendix has not been proved.

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## CYSTIC DISEASE OF THE BONES

A STUDY OF FIFTEEN CASES

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### I CLINICAL REPORT BY DR ASHHURST

Diseases of any tissue in the body may be classified conveniently into three general categories infections, dystrophies and tumors. But while under each category there are perfectly typical cases, there exist other cases of disease concerning the classification of which there may be uncertainty or disagreement, not to say dispute. The existence of such cases is particularly noticeable in connection with bone diseases, and it is to illustrate this difficulty that the present report of a series of cases of cystic disease of the bones is presented. The only common feature, in some instances, is that in the interior of the bone there existed disease which caused rarefaction, absorption or destruction of bony tissue, with, in many cases, expansion and thinning of the overlying cortex. The causes are various pyogenic bacterial infection, tuberculosis and syphilis, as well as unknown causes including a number of cases of true tumor formation.

1 *Infections*—Let us take first, for example, a case of ordinary hematogenous staphylococcic infection of the bones. In its acute form this infection produces typical acute osteomyelitis, in its chronic form (usually a recurrence or a sequel of an osteomyelitis formerly acute) it produces a scarcely less typical form of chronic osteomyelitis, attended rarely by sequestration, but often by great thickening and hardening of the bone, with a destruction of bone which is slight or almost absent. Such cases sometimes take the form of a Brodie's abscess (1824), a Markoe's abscess (1872), or merely of bone sclerosis without demonstrable pus or central cavity (Garré, 1893).<sup>1</sup> In the subacute

<sup>1</sup> An example of this condition, which is not so rare as has been thought, was reported by the author previously (Med & Surg Rep Episc Hosp 4 110, 1916, Case 5).

type, however, a definite cystic area, not resembling a Brodie's abscess, may develop in the bone affected (Case 1)

But, in addition to frank pyogenic infections, there is also recognized a class of diseases grouped together under the title of infectious granulomas (tuberculosis, syphilis, actinomycosis, etc), in each of which a more or less characteristic granulation tissue is produced. When occurring in bone, these diseases, especially tuberculosis, may take on a cystic character, and, except by pathologic examination of the tissue removed from the cyst, a correct diagnosis between these and other forms of bone cysts cannot always be made. In Case 2, for example, the disease was in all probability tuberculous, but owing



Fig 1—Acute syphilitic periostitis, subperiosteal gumma

to the absence of a pathologic report this is not certain. In Case 3, however, both pathologic examination and the clinical course of the disease demonstrated the tuberculous nature of the infection. It is interesting to note that a case, apparently the exact counterpart of this so far as the roentgen-ray appearances are concerned, has been recorded by Barrie<sup>2</sup> as a case of chronic fibrocystic osteomyelitis.

The only cystic lesions I have recognized in bone as being due to syphilis are of two kinds: those occurring under the periosteum in the acute stages of syphilitic periostitis (Fig 1), and those seen in the short bones and in the ends of the long bones in certain cases of the hereditary form of the disease. A notable example of the latter was illustrated in a patient under my care some years ago, in whom the

<sup>2</sup> Barrie Surg Gynec & Obst 19 42, 1914 (Fig 2)

expanded cystic ends of the long bones and the extremely cystic carpal and tarsal bones represented an abnormal degree of eccentric atrophy (Fig 2) The history of this patient was narrated in detail by Dr John P Jones<sup>3</sup> in 1915 The patient eventually became able to walk without braces, and when last seen (about seven years later) was in good general physical condition



Fig 2—Hereditary syphilis, with cystic changes in the ends of the long bones and in the tarsus

2 *Dystrophies*—These are lesions which may be due to very remote or attenuated infections, or to alterations of congenital abnormalities of metabolism, but whose true cause often remains undetermined All that can be safely said is that they are due to disturbances of nutrition In the autumn of 1914 there came under my care, at the Episcopal Hospital, within a few weeks of each other, two young English patients with recurrent deformity of one lower extremity (one knock-knee, the other bow-leg) developing some years after the opera-

<sup>3</sup> Jones, J P Med & Surg Rep Episc Hosp 3 68, 1915

tive correction of similar deformities. In both, the affected bone was markedly atrophied (eccentric atrophy) and cystic (Cases 4 and 5). Except for possible malnutrition in childhood following the operation, or as a sequel of the operative injury, there appears to have been no adequate explanation of the cystic disease. The elder of the two, a man 25 years of age, was a vegetarian. Possibly this accounted for the dystrophy.

Much more usual than the cases just recorded, but possibly of the same general type, are those known in the literature by the terms bone cysts, cystic osteitis, osteitis fibrosa cystica, etc. Their pathogenesis is still in dispute. Case 6 is a typical example.

Again, of the same general type, but quite rare, are instances of the same disease affecting many bones at the same time—multiple fibro-cystic osteitis, known also as von Recklinghausen's disease (Cases 7 and 8). The relations of this affection to Paget's disease of the bones (osteitis deformans), to osteomalacia and kindred affections in adults remains obscure, though the recent very interesting studies of Dr E. P. Corson White<sup>4</sup> throw considerable light on the subject.

3 *Tumors*—The term tumor is here used in a clinical sense, inasmuch as the pathologic and pathogenic sense of the term is in dispute. From an academic point of view, I admit that any cell in the body may form a tumor, and that this tumor may be of the embryonal (malignant), intermediary (questionable) or adult (benign) type. The two extremes (benign and malignant) are not difficult to recognize, but, in accordance with the dictum "*Natura non facit saltus*," there are a great many tumors of intermediary type, which, as Ewing says, "are neither benign nor malignant." And then there are lesions which are neither granulation tissue (inflammatory reaction) nor yet true tumors. Thus, at the end of the tumor classification which is nearest the class of cases just discussed, especially to that illustrated in Case 6, I place Case 9, an instance of "cystic osteitis with giant cells," as our pathologist named it. Next to it (Case 10), I place a case of "giant cell sarcoma" (myeloma)<sup>5</sup> which returned after primary evacuation, then, under the

4 White, E. P. C. Osteitis Deformans in Monkeys, *Arch. Int. Med.* 30:790 (Dec.) 1922.

5 The term myeloma I prefer to that of giant cell sarcoma or giant cell tumor. The term myeloplaxoma, originally chosen by Eugene Nelaton (1860) to designate this benign tumor, was abbreviated into myeloma by Malherbe in his book on sarcoma (1904) and the latter term is in common use in Great Britain and Canada, as well as in France. It is intended to describe a benign tumor of bone marrow. A malignant tumor of bone marrow is a sarcoma. A tumor of intermediary type may well be called a myeloid sarcoma (Case 13). A myeloma should, of course, be distinguished from the general disease called myelomatosis or multiple myeloma, with which the benign tumor myeloma has no connection.

influence of Coley's toxins swelled up larger still, ruptured, discharged its contents and gradually became condensed until only a small bony tumor remained. Following this comes a myeloma (Case 11), which undergoing favorable evolution cured itself without any operative treatment, while Case 12 represents on the contrary, a patient with a myeloma which recurred in semisarcomatous form after evacuation, but who is now well nearly nine years after radical excision of the recurrent disease. Here we appear to have progressed from the least neoplastic type of growth (Case 9) to one which becomes semimalignant (Case 12).

A closely similar condition clinically was seen in Case 13 but the mere fact that it occurred in a much older patient made us suspect that clinically it might be a malignant process and our pathologist at first classed it as a spindle cell sarcoma, but later revised his diagnosis to "giant cell sarcoma of bone marrow with areas showing early spindle cell sarcoma."

Finally, to round out the series of cystic tumors, I include an instance of chondroma undergoing cystic change (Case 14) and a case of cystic disease of the tarsal scaphoid (Case 15) grossly resembling a myeloma, but proved by microscopic study to be an angioma.

## II INTERPRETATION OF ROENTGENOGRAMS OF CYSTIC DISEASE OF THE BONES BY DR. BROMER

When a roentgenologist is called upon to make a diagnosis of a cystic condition in bone on the roentgenogram negative, the mere state-

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6 In regard to the presence of spindle cells and round cells in bone cysts, Bloodgood (*J. Radiol.* 1:168 [March] 1920) remarks that in almost all of his cases of bone cysts with osteitis fibrosa he has found cellular areas with spindle cells or round cells. The spindle cells are apparently of the connective tissue type which ultimately form fibroblasts and fibrous tissue, and the round cells are either osteoblasts which have not yet formed bone or cells which arise from proliferation of the endothelial cells of blood vessels. In a number of his reported cases in which tissue was sent to the laboratory for diagnosis, a diagnosis of sarcoma was made from the frozen section, while further study and the patient's clinical course showed the lesion to be benign. Similarly, our pathologist, Dr. C. Y. White, has frequently called our attention to perfectly typical areas of spindle cells from which, alone, any pathologist would make a diagnosis of sarcoma, yet study of other areas in the same section, and of sections cut from other blocks, rendered the diagnosis of sarcoma very doubtful or entirely precluded the idea of malignancy. Dr. White employs the convenient terms "giant cells" and "gigantic cell," to describe, by the former, the ordinary epulis type of multinucleated cell named myeloplax by Eugene Nelaton (1860), the first writer to describe systematically as a benign non-sarcomatous tumor the "giant cell sarcoma", while by the term "gigantic cell," Dr. White designates the multinucleated "true tumor giant cell," which by many is considered indicative of malignancy, being found in carcinoma as well as in sarcoma.



ment that rarefied areas, a cystic process, exists is neither satisfactory to himself nor to the surgeon. If the diagnosis of the causative factor is difficult for the surgeon to make clinically, it is equally difficult for the roentgenologist and the same might be said for the pathologist. It has been my experience, after a diagnosis of sarcoma had been made from the roentgenograms, to have the pathologist return a report on the excised specimen of chronic inflammatory tissue. Six months afterward, he returned a report of spindle cell sarcoma, when a second excised specimen had been sent to him. Further cutting of the first specimen revealed the same cells in it as were later found in the second.

The purpose of the presentation of these roentgenograms is to emphasize the impossibility, at times, of an exact roentgen-ray diagnosis. If nothing original or new is advanced, it seems well worth the effort to reproduce roentgenograms of varied lesions showing striking similarity, for by close study of them something of importance is gained.

Dr Ashhurst has generally classified the foregoing lesions in three categories: infections, dystrophies and tumors. Lovett<sup>7</sup> has pointed out the impossibility, in the case of infections, of differentiation of syphilis, chronic osteomyelitis and tuberculosis, by means of the roentgen ray alone. Bloodgood<sup>8</sup> has shown the impossibility of such differentiation in the case of tumors, especially cysts, giant cell tumors and central sarcomas. Ewing<sup>9</sup> has pointed out the difficulties of the pathologist.

The more one reads the existing literature, the more disheartened he is as a result of the lack of assistance. Numerous classifications abound. Baetjer<sup>10</sup> has attempted to aid by his laws of possibilities, age, etc., but their practical application, when one is confronted by the actual lesion, is not easy. It is no bold assertion to say that every roentgenologist feels his limitations, in this respect.

It is our plan to set forth, for each roentgenogram, explanatory notes, stating the points of similarity, difficulties in diagnosis and any other characteristics which serve to strengthen or confirm our opinion of the exact underlying pathologic process in each lesion.

#### REPORT OF CASES

CASE 1—*Osteomyelitis of shaft of humerus resembling cystic disease.*  
History—C. R. C., a red haired youth aged 19, came under my care in

7 Lovett, R. W., and Wolbach, S. B. Roentgenographic Appearance, Diagnosis, and Pathology of Some Obscure Cases of Bone Lesions, *Surg., Gynec. & Obst.* **31** 111 (Aug.) 1920.

8 Bloodgood, I. C. The Diagnosis and Treatment of Benign and Malignant Tumors of Bone, *J. Radiol.* **1** 147 (March) 1920.

9 Ewing, James. A Review and Classification of Bone Sarcomas, *Arch. Surg.* **4** 485 (May) 1922.

10 Baetjer, F. H., and Waters, C. A. Injuries and Diseases of the Bone and Joints, New York, Paul B. Hoeber, 1921.

the Episcopal Hospital, Sept 14, 1921 complaining of pain and swelling of the right arm. He had been in the hospital on numerous occasions previously, the first time in the summer of 1914. At that time, when 12 years of age, he was admitted to the medical service with the diagnosis of typhoid fever, but staphylococci were grown in cultures made from his blood, and eventually he was transferred to my care with pains in the right sacro-iliac region and hip. After rest in bed with weight extension for about four months, he was discharged apparently well, no local lesions having developed. About a year later, in January, 1916, an abscess developed and later discharged over the right sacro-iliac joint. Because of this condition he was readmitted to the hospital. Although there seemed to be free drainage, he continued to have a hectic rise of temperature for a week after admission, so operation was undertaken. Roentgenographic examination after bismuth injection of the sinuses revealed that one apparently extended to the right acetabulum, but the clinical diagnosis was necrosis of the sacrum. At operation (Jan 21, 1916), I traced one sinus to the region of the great trochanter, but it led to no bone lesion. Another sinus was followed to the lateral border of the sacrum from which a few small cortical sequestrums were removed. The wound was swabbed with pure phenol and packed with gauze. Convalescence was uneventful, and he was discharged with the wound healed, two or three months later. More than a year later (in 1917) while at home, two sinuses developed in the right thigh near the hip and discharged a little pus for more than a year. He was again in the hospital for three months, under Dr Gill's care (during my absence in France), but no operation was performed. The sinuses did not heal finally until 1919, and in September, 1919, he was again in the hospital and was treated with weight extension for three months because of pain. He went home with the sinuses still healed, and they have remained healed ever since. He has now had no symptoms referable to the hip for two years. During the year 1919, however, a lump on the anterior surface of the right arm above the elbow formed and again disappeared several times. It was finally lanced, and a spicule of bone was removed. The sinus healed in about a month, and his arm had given him no further trouble until recently.

In June, 1921, three months before the present admission to the hospital, he was hit on the right arm by a baseball, and some time later fell from a motor cycle and may have injured his arm. Two months before, he had some dull pain in the arm and was treated by his family physician for neuritis. The pain commenced again a week previously, and the arm began to swell. Then the pain diminished.

*Examination*—On admission, Sept 14, 1921, there were noted the scars of healed sinuses about the right hip, thigh and sacro-iliac region. The movements of the hip were normal and painless. The right arm was swollen, red and hot. It was not very painful even on deep pressure. There was palpable bony thickening in the middle of the shaft. About 2 cm below this area, on the anterior surface of the arm, was the scar of a healed sinus. The roentgen-ray report by Dr R S Bromer stated, "There is a fusiform swelling of the shaft with much periosteal thickening which is laid down longitudinally. There is widening of the medullary canal and a shadow suggestive of a sequestrum lying within it. I hardly think this is due to a new growth but to an osteomyelitis" (Fig 3).

*Operation*—Sept 16, 1921, an incision, 20 cm long, was made between the biceps and triceps, exposing the thickened roughened shaft with one cloaca

on its anterior surface affording admission to a cavity about 5 cm in length in the medulla. No sequestrum was found. The involucrum was removed on the lateral surface of the humerus for a distance of 15 cm, both sides of the gutter being cut down until only half the thickness of the bone remained. The wound was wiped with picric acid (2 per cent alcoholic solution) and closed.



FIG. 3 (Case 1)—Staphylococcic osteomyelitis of humerus, subacute, abscess with cystic appearance

with deep sutures of silkworm gut, with an iodoform gauze wick emerging at the lower angle, and the arm was bound to his side and a shoulder cap applied.

Course—Oct 1, 1921, the wound was nearly healed. There was a slight purulent discharge from the lower angle.

September, 1922, the wound broke open once, three months after operation, but healed in a week and has remained healed since

March, 1923, there was normal function and no disability whatever

*CASE 2—Bone cyst of the tibia History*—C G, a brunette Italian girl, aged 5 years, had always been well except for measles and whooping cough in infancy For about two years before coming under observation, there had been some swelling around the left ankle no history of injury was obtainable Lately there had been much pain in walking

*Examination*—On admission to the Episcopal Hospital, Aug 25, 1913, the soft parts over the lower end of the left tibia were swollen and tender There was no redness and no heat The tissues around both malleoli were puffed up,



Figure 4



Figure 5

Fig 4 (Case 2)—Cystic osteitis, probably tuberculous, of lower end of tibia

Fig 5 (Case 2)—Cystic osteitis, probably tuberculous, of lower end of tibia

and there was marked tenderness on movement of the foot, especially on forced dorsal flexion A roentgenogram (Figs 4 and 5) revealed a bone cyst of the lower end of the tibia, the ankle-joint appearing normal

*Operation*—Aug 27, 1913, under Esmarch anemia, a curved incision was made over the seat of disease, and a flap of skin and subcutaneous tissue turned aside The periosteum was slightly thickened, and the cortex slightly hyperemic The cortex was about 2 mm thick, and when this was removed a yellowish white cyst wall bulged into the opening When this was cut through with scissors, some semifluid matter resembling tuberculous pus, oozed out, and then considerable cheesy matter was evacuated, but no free fluid There was a good deal of carious spongy red bone surrounding the cavity, and

it was thought to be a tuberculous abscess of bone (Brodie's abscess) On the posterior wall of the tibia, the cyst had perforated the cortex over an area about 3 mm in diameter The cyst cavity was the size of a pigeon's egg and extended down to the epiphyseal cartilage The cavity was scraped clean and filled with iodoform bone wax (Mosetig-Moorhof), no drainage was established The leg was dressed in plaster of Paris

*Course*—September 3, the gypsum dressing was removed because of pain in the leg A little of the wax was discharging between two sutures A new gypsum case was applied, with a window over the wound

October 3, no discharge had come from the wound since the last note The wound was now healed

October 10, the patient was walking in a gypsum case

October 15, the case was removed Swelling over the ankle was less A new case was applied without any window over the wound

November 5, the case was removed There was no swelling, and good motion in the ankle A brace was ordered

November 28, the patient was sent home walking well in the brace A roentgenogram made before the patient went home revealed considerable concentric growth of bone around the iodoform wax plug, which had been slightly absorbed

Feb 12, 1914 (six months after operation), the leg looked practically normal The ankle could not be dorsiflexed beyond 90 degrees There were no symptoms The patient walked well, and still used the brace (It has been impossible to trace the patient)

*Pathologic Report* (Dr C Y White)—Culture and smear from the cyst were negative (Unfortunately, the cyst wall and contents were mislaid in the operating room and did not reach the laboratory in fit condition for histologic study or for inoculation into guinea-pigs)

*CASE 3—Tuberculous cyst of ulna History*—J C, a brunette boy, when about 6 years old, fell and hurt his left elbow He seemed to have suffered no particular disability as a result, but two years later (July, 1914) he applied to the orthopedic dispensary of the Episcopal Hospital because of limitation of motion

*Examination*—There was decided limitation of rotation in the forearm, and the elbow could be flexed only to 50 degrees and extended to 130 degrees There was no pain, no heat and only slight thickening of the elbow region A roentgenogram revealed a cystic condition of the upper end of the ulna apparently extending to the joint surface (Fig 6) It was thought to be a 'benign bone cyst,' and, after keeping the child under observation for four months and finding no change in the local condition, operation was advised and agreed to by the parents

*Operation*—Nov 4, 1914, under Esmarch anemia an incision was made over the subcutaneous surface of the ulna below the olecranon The periosteum was incised and reflected The cortex appeared unduly inflamed, with a large number of bleeding points, and was soft and easily removed by a gouge, without the use of a hammer The cortex was 0.5 cm thick and when it was removed a smooth fibrous layer was exposed, which constituted the cyst wall Enough of the overlying cortex was removed to expose the cyst wall fairly well over an area approximately 2 by 4.5 cm An attempt

was then made to enucleate the cyst without rupture, but this proved impossible since, at the coronoid process of the ulna and over the entire articular surface, the cyst wall was densely adherent to the bone, dipping down into irregular notches and depressions. Those portions of the cyst wall which were not removed with the cyst contents were scraped off the adjacent bone



Fig 6 (Case 3)—Cystic osteitis, tuberculous, of upper end of ulna

with the sharp spoon. The contents of the cyst resembled granulation tissue. No fluid was present. The cavity in the ulna was filled with iodoform bone wax, and the periosteum and then the skin were tightly sutured. The Esmarch bandage was not removed until after the dressings had been applied.

*Pathologic Examination* (Dr C Y White)—This revealed tuberculous osteomyelitis. Injection of the tissue into a guinea-pig was positive for tuberculosis.

This report is of interest, especially as the roentgenogram did not suggest a tuberculous process. The roentgenogram is practically identical with that of the second case reported as chronic fibrocystic osteomyelitis by Barrie.<sup>11</sup>

*Course*—November 23, there had been a little discharge of wax since operation.

December 7, the wound was firmly healed.

December 18, a plaster-of-Paris case was applied, the laboratory report of the tuberculous nature of the lesions having been received.

March, 1915, the gypsum case was removed and the arm carried in a sling.

May. As heat in the elbow persisted, an internal angular splint was applied, in addition to the sling.

June. There was no heat or swelling. The splint was removed.

July. Use of the sling was discontinued.

October. Motion of from 50 to 120 degrees was possible. There was never any pain.

August, 1916. Motion of from 70 to 140 degrees was possible. There were no symptoms.

November. Motion of from 45 to 115 degrees was possible. The patient played ball and had no disability. It was believed that if motion did not improve when epiphyseal growth was complete, excision of the elbow might be advisable. A roentgenogram revealed no vestige of wax remaining. The upper end of the ulna was rarefied, but much of the cortex had reformed, apparently of normal density.<sup>11</sup>

*CASE 4—Fibrocystic osteitis of femur developing after operation for knock-knee.* *History*—M E, a brunette, aged 16 years, was admitted to the Episcopal Hospital in October, 1914, complaining of disability from recurrence of a knock-knee deformity in the left lower extremity. When 3 years of age she had been operated on in England for knock-knee, being told at that time that she had only cartilage, no bone, in the knee. The deformity gradually recurred.

*Examination*—There was lateral movement in the knee joint through an angle of 50 degrees (from 180 to 130 degrees), and in flexion the patella luxated externally, entirely disabling the patient. The left lower extremity was 2 cm shorter than the right. There were scars over the inner surface of the upper end of the tibia, and above the internal condyle of the femur, which she said were those of the operation, thirteen years previously. A roentgenogram showed a cystic area in the lower end of the femur.

*Operation*—Oct 24 1914, an incision about 10 cm long was made from the patella upward between the rectus and vastus internus muscles. The latter was cut through, exposing the femoral shaft. The quadriceps bursa was then raised from the femur, and a wedge of bone was cut from the median surface of the femur just above the internal condyle. The cortex was very thin, fracturing almost like an eggshell, and the marrow was almost fluid. Good correction of the deformity was secured after removal of the wedge, by breaking the thin cortex on the lateral margin of the femur by adduction of the leg on the thigh. A plaster-of-Paris dressing was applied.

<sup>11</sup> During the author's absence in France (1917-1919), Dr Gill performed an excision of the elbow for recurrence of tuberculosis.

*Pathologic Report* (Dr C Y White) —No organisms were visible in a smear made from the fluid in the medullary cavity, and a culture showed no growth. A guinea-pig inoculation was negative for tuberculosis. Histologically, the sections from the marrow showed only chronic granulation tissue becoming fibrous.

*Course* —The gypsum case was removed two months after operation, but a brace was worn for a year, supporting the knee against undue strain. Five years and three months after operation, the patient was reported to be in good health, with no recurrence of the deformity and normal use of the knee.

*CASE 5—Fibrocystic osteitis of tibia developing after operation for bow-leg*  
*History* —A M., a brunette man, aged 25, was admitted to the Episcopal Hospital Oct 24, 1914, complaining of instability in the left knee, which was subject to recurrent sprains. He had been operated on in England ten years, or more, previously for bow-legs, and for the last five or six years this deformity had been returning, especially in the left lower extremity where the bowing was quite marked, owing to outward curvature of the tibia.

*Examination* —Roentgenograms showed changes in the head of the tibia suggesting cyst formation. The knee was bowed outward at an angle of 160 degrees, there was moderate (from 5 to 10 degrees) lateral motion in the joint, and the limb was 2.5 cm shorter than its fellow.

*Operation* —Nov 6, 1914, a skin flap was turned up over the subcutaneous surface of the upper end of the left tibia, and the periosteum was retracted. Transverse osteotomy was performed about 6 cm below the level of the knee joint, dividing the entire median surface of the tibia. The medullary cavity seemed to extend unduly far toward the bone end, it resembled currant jelly in appearance, but was more friable. A piece of bone, 2.5 by 1.25 by 1 cm, was cut from the cortex of the tibia shortly below the site of the osteotomy. This was inserted in the gap made by correcting the bow-leg deformity. The bone wedge effectually prevented its recurrence. A plaster-of-Paris dressing was applied.

*Pathologic Report* (Dr C Y White) —Tissue removed from the marrow cavity, on guinea-pig inoculation was negative for tuberculosis, but after sufficient tissue had been used for this purpose the specimen was not satisfactory for histologic examination.

*Course* —Dec 31, 1914, a brace was applied after the gypsum case had been removed. The knee was straight. Jan 18, 1915, the patient went home wearing a brace, but walking without crutches. The patient has not been traced.

*CASE 6—Bone cyst involving the upper end of the humerus* *History*<sup>12</sup> —J R., a brunette boy, aged 12 years, fell and injured the right shoulder in the summer of 1911. He was treated for a sprain. He fell again in November 1911, and broke the humerus. About ten days after this injury he was admitted to Dr Frazier's service in the Episcopal Hospital, and came under my care. There evidently was an unreduced fracture of the upper end of the humerus. A roentgenogram confirmed the diagnosis, nothing else abnormal was noted at the time. Excellent reduction, as shown by another roentgenogram, was secured under a general anesthetic, and recovery of perfect function was uneventful.

About three months later (March, 1912), another roentgenogram was made to see whether there had been any permanent injury to the epiphyseal cartilage. There were now indubitable evidences of a change in the upper portion of the medulla of the humerus. The whole upper end of the diaphysis was thickened,

<sup>12</sup> Compare Med & Surg Rept Episc Hosp 1 290, 1913



two rarefied areas in the medulla were surrounded by denser bone, and there were indications of bony trabeculae crossing the rarefied areas. The functions of the joint were perfect, there was absolutely no deformity, and there were no subjective symptoms of any kind. For these reasons no treatment was instituted, but the boy was kept under observation. Reexamination of the original roentgenograms revealed thickening of the upper end of the humerus, probably indicating the presence of disease at that time (November, 1911).

In August, 1912, nine months after the injury, another roentgenogram was made. This showed the cystic change more developed, with thinning of the cortex. There were no subjective symptoms whatever, and all of the functions



Fig 7 (Case 6) —Bone cyst, upper end of humerus, with pathologic fracture (Courtesy of Lea and Febiger, from Ashhurst's "Surgery")

of the shoulder joint, including external rotation and abduction, were fully preserved. On palpation, however, a distinct though slight thickening of the humerus could be detected, when compared with the other arm.

The boy fell again, Jan 6, 1913, and injured the right shoulder. He came at once to the Episcopal Hospital and was seen by me. A roentgenogram (Fig 7) showed a partial fracture of the cyst wall below the greater tuberosity. The parents then consented to operation.

*Operation*—Jan 10, 1913, the patient was etherized, and an Esmarch bandage was applied above Wyeth's pms, as for shoulder joint amputation.

An incision was made from the coracoid process down to the insertion of the deltoid muscle along the interspace between the deltoid and pectoralis major. The cephalic vein was left attached to the deltoid. Sterile gauze was then sutured to the skin margins of the wound. With another scalpel the intermuscular incision was deepened, and the periosteum was incised just to the outer side of the long tendon of the biceps. The periosteum was thickened, but no distinct new subperiosteal bone was present. The fracture on the outer side

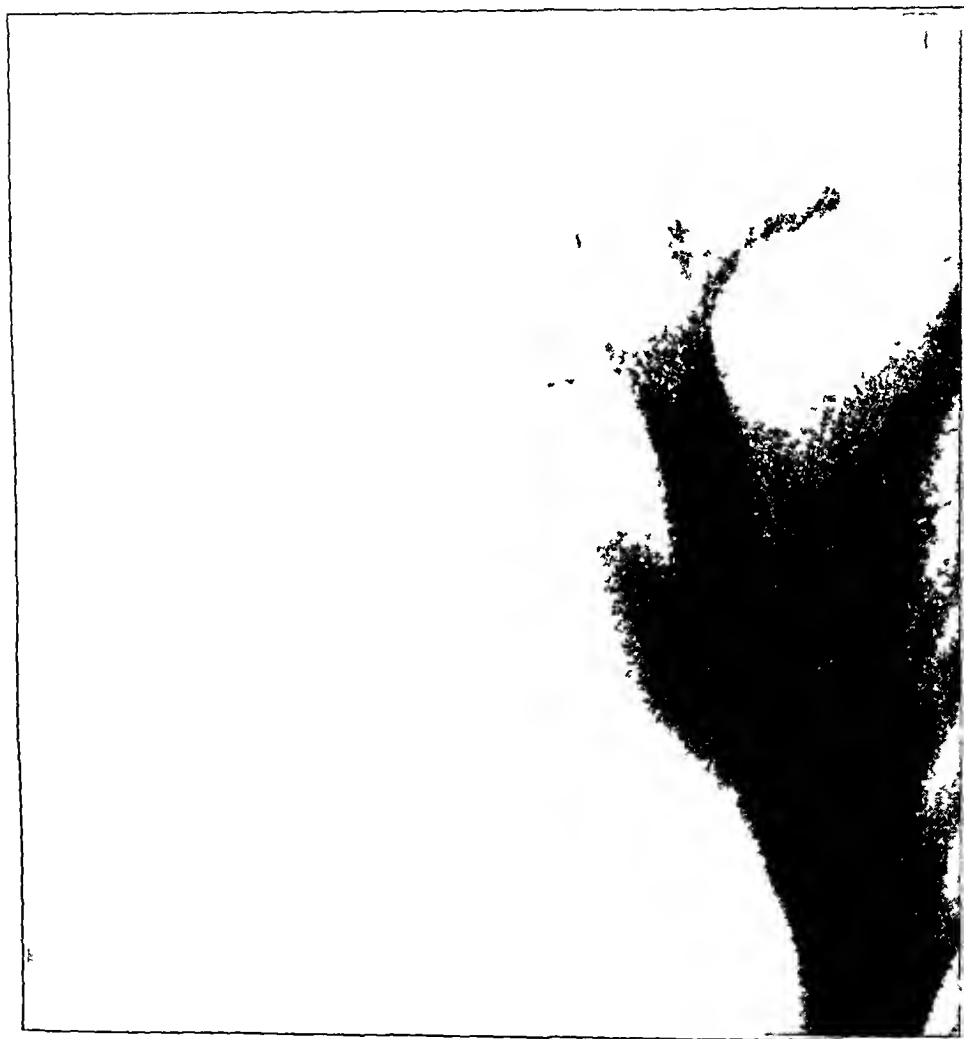


Fig 8 (Case 6) —Humerus, ten years after operation

of the surgical neck was thus exposed, one shell of the cortex, as shown in the roentgenogram, stood out from the shaft. From this there was a faint line of fracture running transversely inward. No rotation of the lower fragment on the upper was possible.

The cortex, which was about 2 to 3 mm thick, was then cut away with a gouge, exposing the medullary cavity which was filled with thin blood-stained fluid. This was sucked out with a syringe and sent to the laboratory for examination. There was about 10 cc of fluid. A few masses of currant jelly

like medulla were also removed and sent to the laboratory, as was a section from the cyst wall. There were no areas of whitish tissue, characteristic of fibrous osteitis. The interior of the expanded cortex was curetted with Volkmann's sharp spoon, the opening in the cortex being enlarged until about 8 cm long and 2 cm broad, the defect extending from the level of the epiphyseal cartilage to the insertion of the deltoid muscle. At these limits the cortex and medulla seemed to become normal. The cortex on the median side of the bone opening was then crushed in, and the wound was closed in layers without drainage—first, the periosteum, then the deep fascia, and finally the skin. The time consumed by the operation was one hour.

The Esmarch bandage and Wyeth's pins were removed after the wound had been dressed. A shoulder cap was applied, and the arm bandaged to the side.

*Course*—At the first dressing, January 22, all the skin sutures were removed. There was moderate serous discharge (subcutaneous) from below the lowest suture. The rest of the wound was healed. The arm was dressed again three days later, when there was no discharge, the wound being soundly healed. The boy was sent home this day, two weeks after operation.

There have been no symptoms since operation, and in October, 1922, nearly ten years after operation, there was no evidence of recurrence and no disability (Fig 8).

*Pathologic Report* (Dr C Y White)—Cyst Wall. Small fragments of the inner surface and wall of the cyst showed, on histologic examination, normal bone trabeculae, faced by a narrow margin of fibrous tissue. The latter separated the cyst contents from the bony structure and consisted of typical fibrous tissue cells without other cellular infiltration. The bone fragments consisted of normal bone trabeculae without cellular infiltration other than is common to spongy bone.

*Cyst Contents*. The contents of the cyst showed yellowish fluid containing blood clots. Smears made from the fluid showed the following cellular contents: polymorphonuclear leukocytes, 14 per cent; mononuclear cells, 2 per cent; transitional cells, 1 per cent; lymphocytes, 72 per cent; eosinophils, 2 per cent; neutrophilic myelocytes, 9 per cent.

No nucleated red cells, no giant cells, a few fibrin fibrillae and serum were found.

*Bacterial Cultures*. Anaerobic and aerobic cultures were negative. No bacteria were observed in the various smears examined. A complement fixation test for syphilis made on the fluid from the cyst gave a negative reaction.

*CASE 7—Multiple cystic osteitis. History*—E J, a brunette girl, aged 19, was admitted to the Episcopal Hospital, Oct 12, 1920. The general health had always been good. When 7 years of age (in 1908) while walking on the street, the patient fractured the left femur—apparently a spontaneous fracture. She was taken to the Chester Hospital, where she said the bone was rebroken seven times but finally united with marked deformity. In 1914 (at 13 years of age) she sustained a fracture at the middle of the right femur. Union occurred without deformity. Dr H M Armitage operated at the Chester Hospital on the left femur twice in 1915 for deformity. (He writes that both operations were merely osteotomies with straightening of the bone for malunion following repeated fracture. He saw no indication then of any cystic disease.) In 1916 she injured the upper third of the left leg (below the knee) while playing on a sliding board, but she was not confined to bed and did not wear a splint. She had had pain in the left leg until the last year. Anteroposterior bowing of the right leg had been developing gradually for years.

*Examination*—The patient could walk with crutches or other support as far as a mile, progressing very slowly, crossing one leg in front of the other as indicated in the accompanying illustrations (Figs 9 and 10)

Only the lower extremities were affected, the left femur and leg bones being much more deformed than the right. The right lower extremity from the anterosuperior spine of the ilium to the internal malleolus measured 74 cm, the left 71 cm, in straight lines, not allowing for the distortion of the limbs (Figs 11, 12 and 13)

The left femur slightly above the middle was bowed outward, making an angle of about 135 degrees, open toward the midline of the body (Fig 13). There



Fig 9 (Case 7)—Appearance of legs before operation, multiple fibrocystic osteitis, showing ordinary cross-legged position in attempts at locomotion

was no abduction possible in the left hip. The left patella was nearly a hand's breadth above the right. Owing to the deformity, the left femur was 7 cm shorter than the right. The left leg (below the knee) was bowed inward in a long curve at an angle of 155 degrees open laterally.

The right thigh was apparently normal except for palpable thickening on the lateral border of the femur, about 10 cm above the condyles. Abduction was possible in the right hip to about 45 degrees. There was marked knock-knee deformity on the right, the thigh and leg making an angle of 145 degrees.

The blood Wassermann reaction was negative, and there was no Bence Jones protein in the urine which was otherwise normal, as was the blood.

*Treatment*—She was put to bed with weight extension (longitudinal) applied to both legs, lateral traction to each knee, pulling the knees apart, and a band over the apex of the deformity of the left femur pulling toward the right.

During her stay in the hospital metabolic tests were made by Dr A A Walkling under the supervision of Dr C Y White, director of the hospital laboratories, but they gave no conclusive results

Dec 17, 1920, after two months in bed with extensions as above described, the position of the left leg having been slightly improved, the patient was etherized, and, after forcible abduction of the left hip until the femur was heard to crack at the site of the old fracture, a plaster-of-Paris dressing was applied from the axillae to the toes on both sides, at the same time keeping the deformities of the knees and legs under as much tension as possible in an effort at correction



Fig 10 (Case 7) —Same patient, with hips abducted as far as possible

*Course*—Jan 13, 1921, the gypsum dressing was removed from the right lower extremity. She was then able to be about the ward in a wheel chair

Feb 5, 1921, the patient was transferred to the Orthopaedic Hospital for further treatment

Feb 12, 1921, under ether a supracondylar osteotomy of the right femur was performed, subcutaneously. The deformity was almost entirely overcome. A plaster case was applied from the toes to the hip

April 5, 1921 the plaster case was removed from the left lower extremity and the pelvis



Fig 11 (Case 7) —Cystic first metatarsal bone of foot



Fig 12 (Case 7) —Deformity and cystic changes in the tibia and fibula of both legs

April 9, 1921, under ether, resection of the left tibia was performed. An incision, 20 cm long, was made, forming a flap with its base on the lateral side of the leg. The periosteum was incised and reflected from the entire circumference of the tibia. The tibia was soft except along the posterior border and

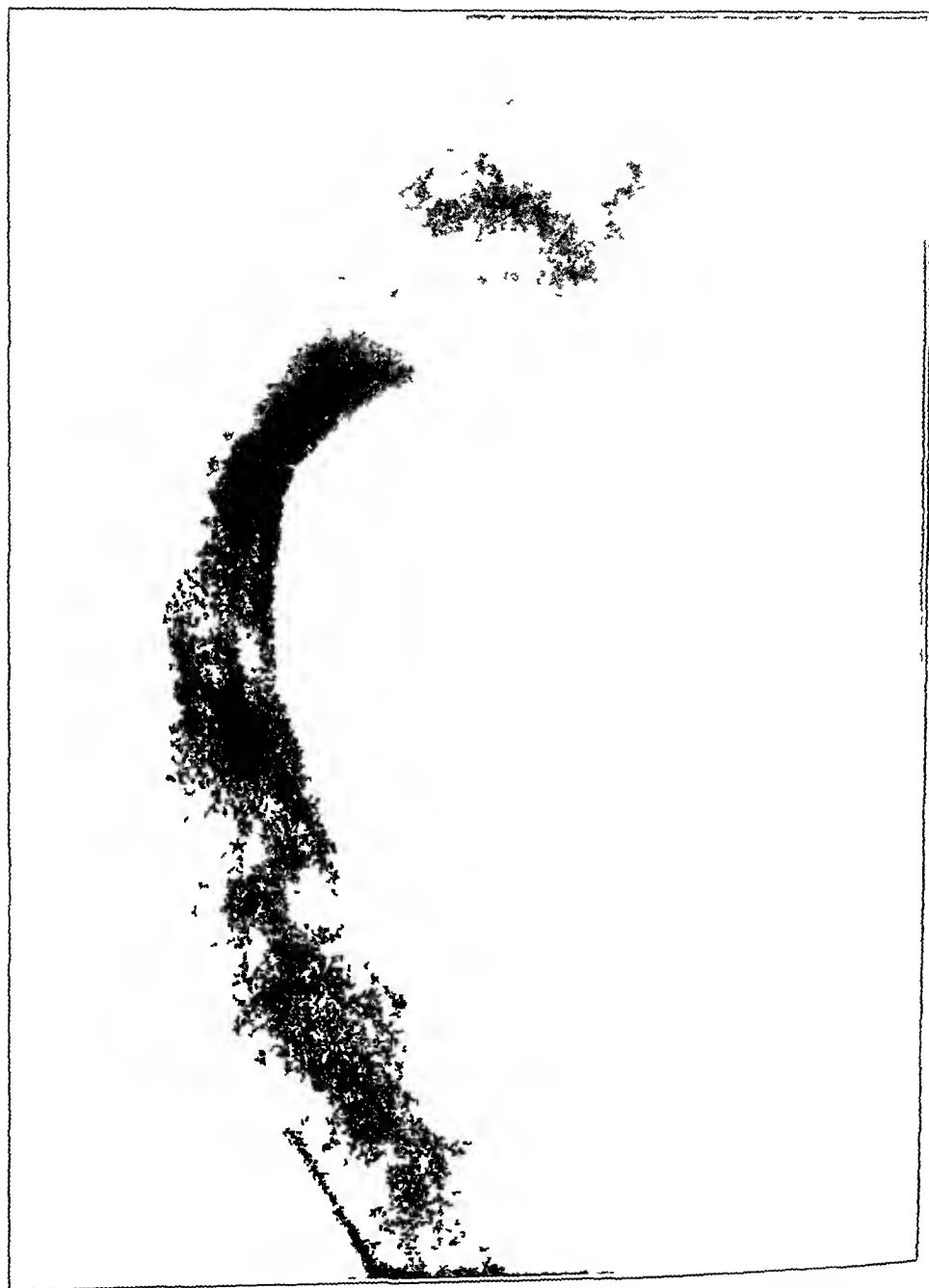


Fig 13 (Case 7) —Left femur, showing deformity and cystic changes

was easily indented by a blunt instrument. Free bleeding occurred from the cortex. The tibia was divided obliquely by the osteotome from the median border out and down to the lateral side below, the section being about 8 cm. A spurting artery from the upper fragment of the divided tibia was controlled by

crushing in the trabeculae. Points of the tibial segments were cut off, and a square notch was cut on the apposing surfaces of the tibia. Much better position was secured by approximating these sections (Fig 14). Reduction was maintained by one Parham band. The periosteum and fascia were sutured with interrupted chromic catgut No 1 and the skin with continuous catgut No 0. The fibula was not divided. The time required was forty-five minutes. A plaster cast was applied from the toes to above the knee.

July, 1921, caliper braces were applied to both lower extremities, and the patient returned to her home, temporarily. She walked with crutches.

September, 1921, she wrote that she was "improving wonderfully." She walked with one crutch.

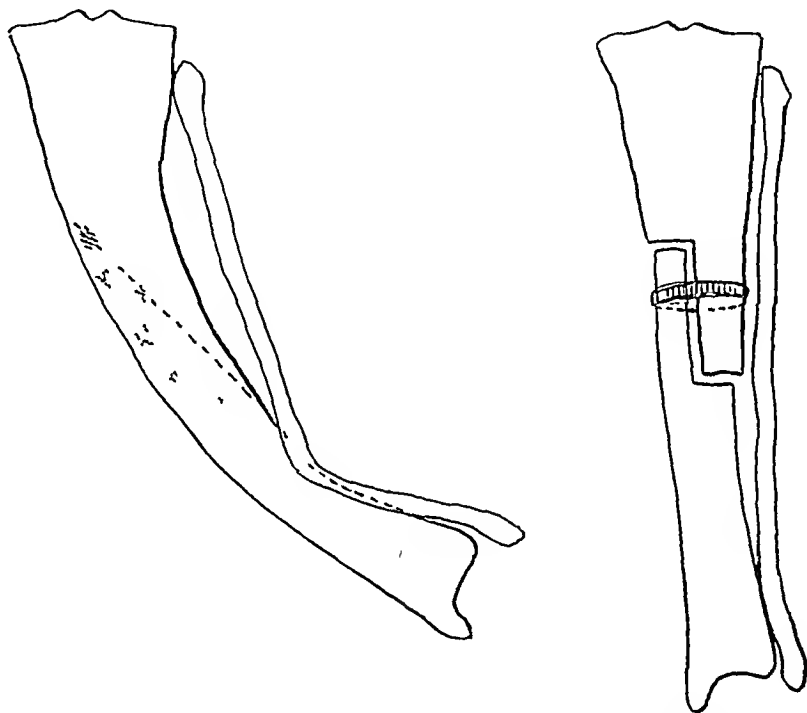


Fig 14 (Case 7) —Diagrams, showing nature of operation on left leg

January, 1923, she still used one crutch, and had slight "cross-legged" progression. The brace was still on the left leg. There was firm fibrous union in the left tibia. She works every day in a mill (Fig 15).

*Pathologic Report* (Dr C. Y. White)—The findings were osteitis fibrosa, no giant cells.

**CASE 8—Multiple fibrocystic osteitis.** *History*—H. R., a brunette youth aged 18, was admitted to my service at the Orthopaedic Hospital, Oct 21, 1916, presenting the deformities shown in the accompanying illustrations (Figs 16, 17, 18 and 19). He had been in normal health from birth until the age of 5 years, from 5 to 7 years of age his bones seemed to soften and bend, and at 9 years of age he suffered his first fracture, from trivial injury. Since the age of 9 years he had had seven other fractures of the limbs, but there had been no fracture for the last few years, and the disease seemed quiescent.



Roentgenograms of the various bones are reproduced in Figures 20, 21 and 23

*First Operation*—In order to correct the deformity of the right leg, resection of the right tibia and fibula was performed Oct 28, 1916. They were dovetailed together according to the diagram in Figure 24. The first dressing was made Feb 10, 1917, three and one-half months after operation, when the gypsum case was removed. The soft parts were healed normally, but there was considerable movement in the tibia. A new case was applied.

*Second Operation*—Dec 16, 1916, operation was performed on the left femur. This bone was almost subcutaneous at the apex of the outward curve. The periosteum was detached by sharp dissection, leaving some flakes of cortical bone



Fig 15 (Case 7) —Results of operative correction of deformities

attached, from the entire circumference of the femur for a longitudinal distance of 8 or 10 cm. The linea aspera jutted out as a very prominent ridge and was difficult to clear. The shaft of the femur was soft and easily dented by the periosteal elevators. It was planned to section the bone as indicated in the first diagram of Figure 25, and then to resect enough of the ends to allow the femur to become nearly straight. It was realized that a simple wedge resection would be inefficient owing to the tension of the soft parts in the adductor and flexor regions. A Hey's saw and osteotomes were used for making the section, but the femur broke across (second diagram of Fig 25) after section *A* was completed. This was, therefore, removed, and section *B* was cut separately. When the femur was straightened, the condition was that shown in the third diagram of Figure 25. The distal half of fragment *A* was replaced in the gap, and the fragments were held together by two encircling pieces of phosphor bronze



Fig 16 (Case 8) —Right lateral view of patient with extreme deformity of extremities from multiple fibrocystic osteitis

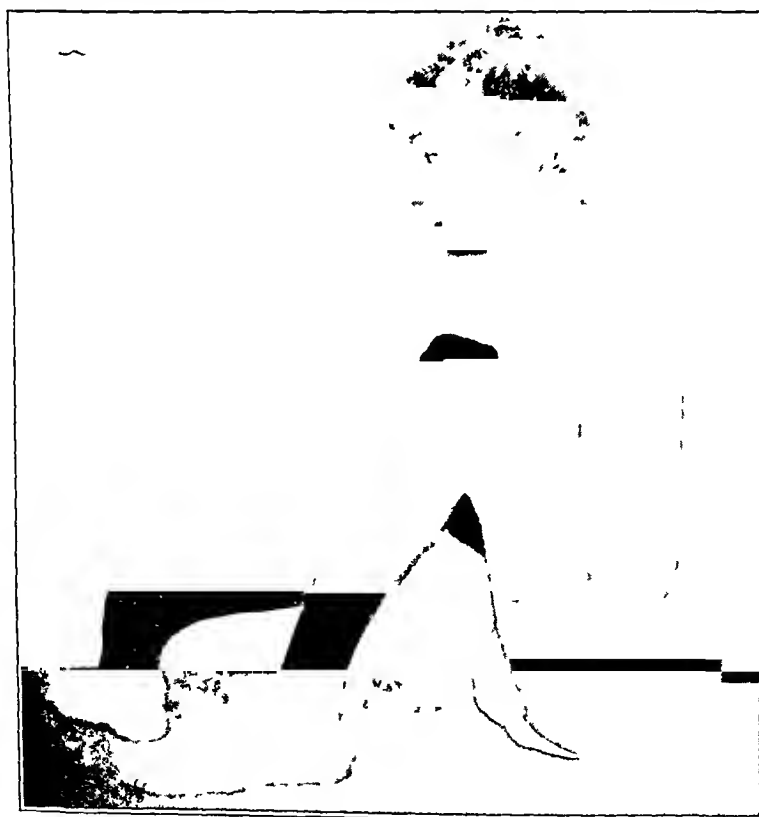


Fig 17 (Case 8) —Left lateral view

wire These were not sufficient to prevent slight motion, but did prevent gross displacement of the fragments, and thus facilitated closure of the soft parts and application of the plaster-of-Paris dressing, which included the pelvis, with the hip flexed to 120 degrees and the knee to 30 degrees, permitting the sole of the foot to lie flat on the bed The first dressing was done Feb 10, 1917 two months after operation The wound was healed except for one point of granulation A new plaster-of-Paris dressing was applied (not including the pelvis), with the hip extended and the knee at an angle of 160 degrees There appeared to be fibrous union in the femur March 7, 1917, preparatory to a second operation on the left leg (compare description of the fourth operation), the case was removed from the left thigh and leg, and a new one was applied including



Fig 18 (Case 8) —Anterior view

the left hip and the thigh to just above the knee Union was not yet firm in the left femur

*Third Operation*—Feb 17, 1916, this was performed on the right femur This bone was bowed outward at right angles below the trochanters and had a cyst 4 cm in diameter, at the apex of the deformity The neck of the femur made an angle of about 80 degrees with the shaft (*coxa vara*) Before the left femur was straightened, the right thigh crossed the left, but since the operation on the left femur, the thighs could be abducted just far enough to put the hand between them The right thigh still was so markedly adducted below the deformity that it made an angle of 45 degrees with the long axis of the body (Fig 26)

At the operation, it was found that the periosteum stripped rather easily from the rough, porous and soft bone. The periosteal elevator easily perforated the cortex into the largest cyst, and about 4 c c of clear fluid was discharged. The periosteum being reflected, the femur was split, by osteotome, longitudinally in the frontal plane of the patient's body for a distance of 12 cm., and the distal end of this section was connected by saw with the extensor surface of the femur, and the proximal end with the flexor surface of the femur. In attempting to



Fig 19 (Case 8) —Appearance of patient with legs extended

straighten the femur by sliding these ends past each other, the distal fragment was fractured nearly transversely, a little below the cyst. The loose fragment, including the cyst, was removed (Fig 22). The ends were then overlapped and encircled by two Parham steel bands, as indicated in Figure 26. After closure of the wound in layers, a plaster-of-Paris dressing was applied from the toes to the villae, with the right femur abducted 45 degrees. The dressing two and one-half months after operation (April 25, 1917), showed the soft parts healed and union firm.

*Fourth Operation*—March 10, 1917, an operation was performed on the left leg. The apex of the deformity (convex medially) was exposed, and the periosteum stripped from the tibia, leaving flakes of bone attached. The bone was cystic in places and quite soft. The tibia was split for 10 cm in the coronal plane, the section emerging on the extensor surface of the tibia at its proximal end and on the flexor (calf) surface at its distal end. The fibula was fractured

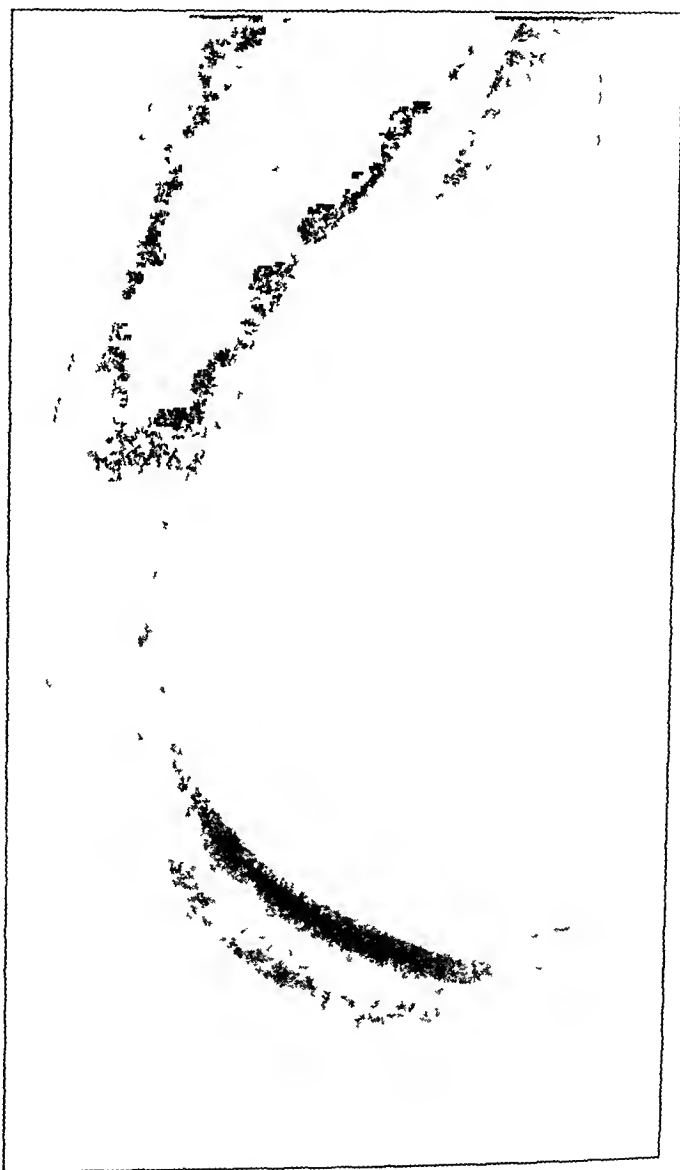


Fig 20 (Case 8) —Right tibia and fibula

purposely by momentarily increasing the deformity of the leg, and the ends of the fragments of the tibia were thus exposed. An artery in the medulla of the proximal fragment ceased to spurt after the application of gauze pressure for a few minutes. The tibial fragments were then overlapped until the axial deformity was nearly overcome, whereupon the superfluous bone was sawed off, causing the fragments to fit together well (Fig 27A and B). These were encircled by two

Parham bands The lower band cut into the soft bone for about 1 cm , but the upper band held firm on the surface of the cortex After closing the wound, plaster of Paris was applied to the leg and incorporated with the gypsum dressing already on the thigh

*Fifth Operation*—This proved fatal to the patient It was undertaken, April 28, 1917, on the right leg, which had been the seat of the first operation, just



Fig 21 (Case 8) —Left tibia and fibula

six months previously It was desired to complete the correction of the deformity of this leg No Esmarch bandage for temporary hemostasis was employed, and none had been employed at any of the previous operations No unusual hemorrhage had been encountered at any of the operations, the spurting artery from the medulla, noted in the account of the fourth operation, was the only

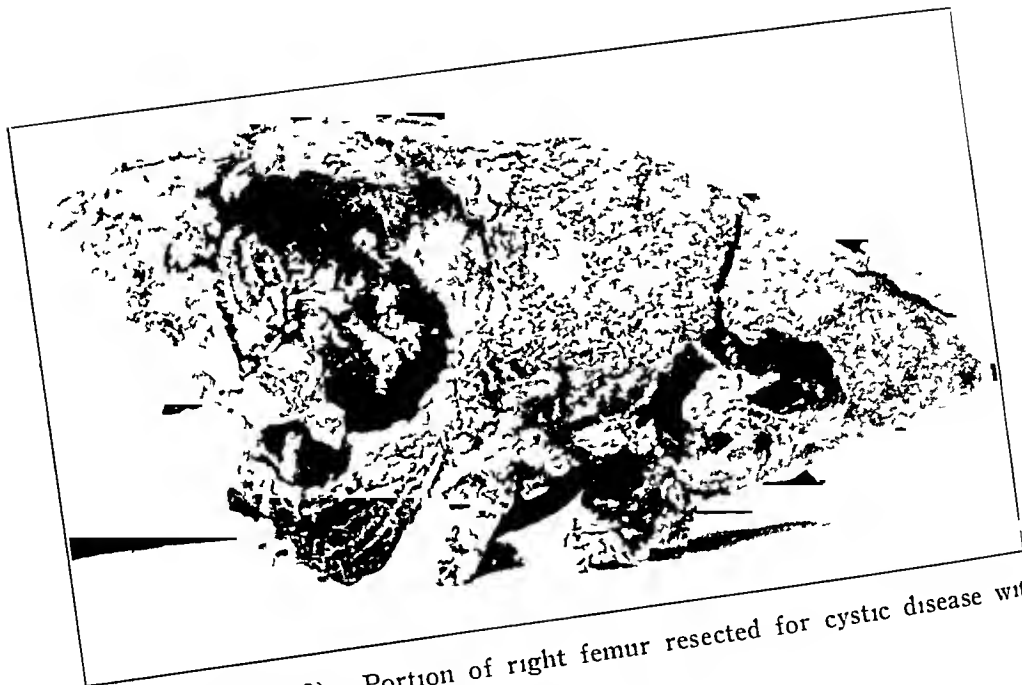


Fig 22 (Case 8) —Portion of right femur resected for cystic disease with deformity, Feb 18, 1917

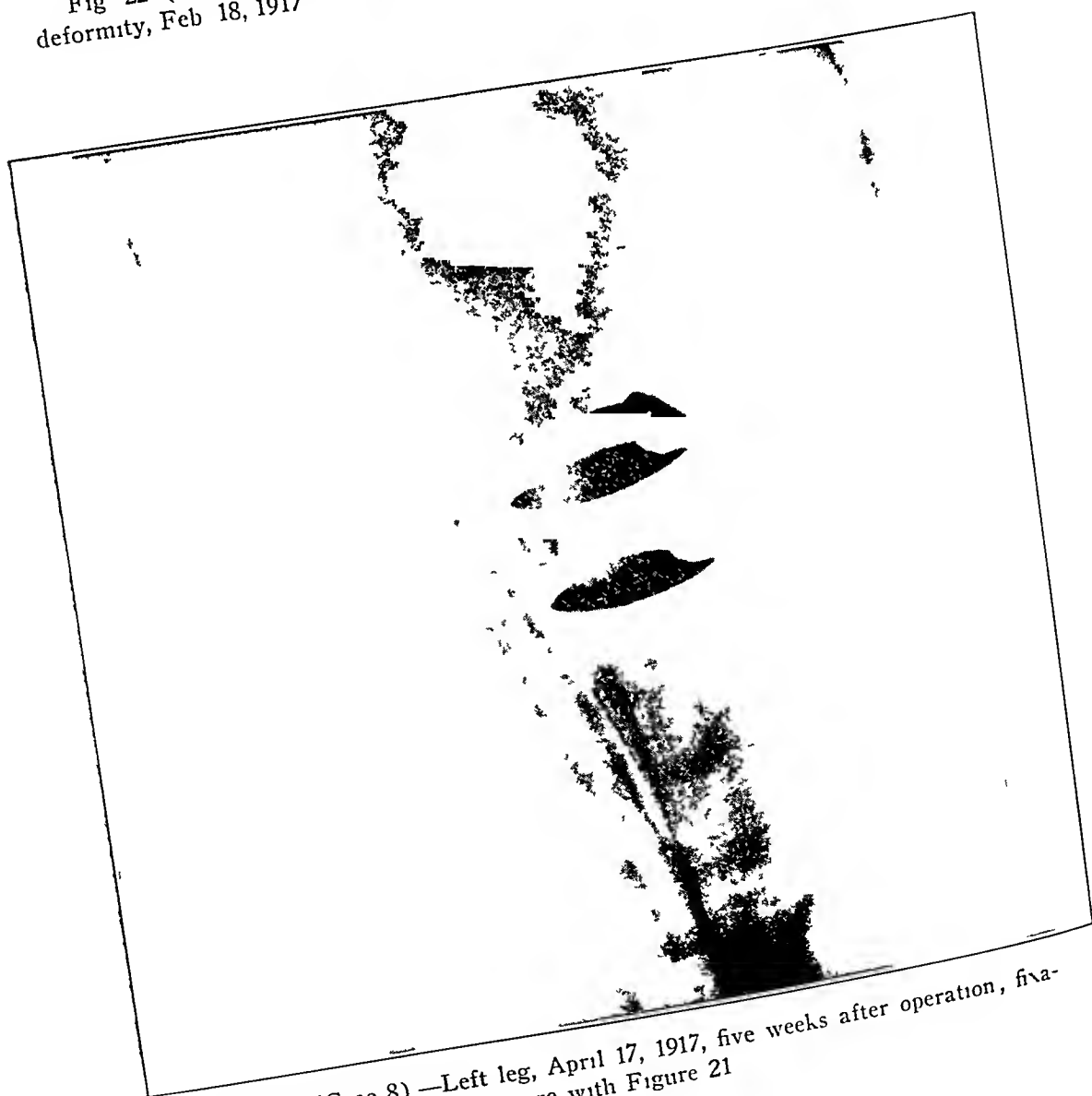


Fig 23 (Case 8) —Left leg, April 17, 1917, five weeks after operation, fixation by Parham bands, compare with Figure 21

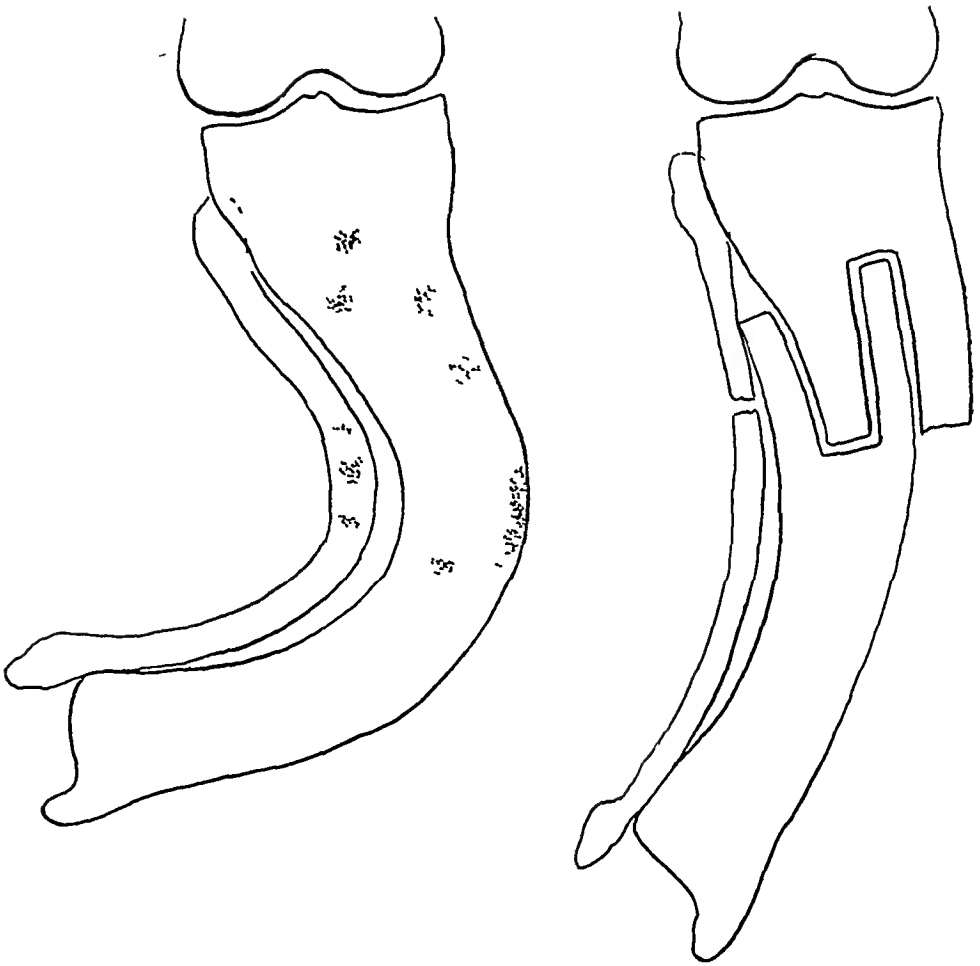


Fig 24 (Case 8) —Right leg resection of tibia, with dovetail joint for fixation This illustration and Figures 25, 26, 27 and 28 are diagrams of the numerous operations employed to correct deformities

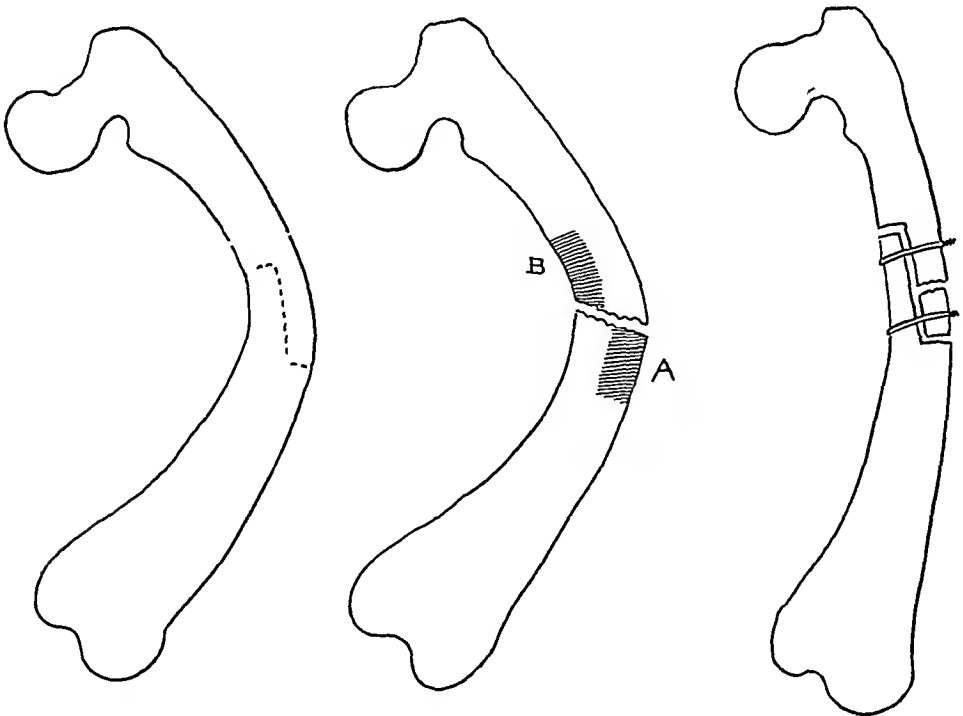


Fig 25 —Left femur resection, with fixation by phosphor bronze encircling wire



bleeding that had been considered worthy of record. But in this, the fifth and last, operation in making the skin incision the internal saphenous vein was cut, and, owing to its being embedded in scar tissue against the periosteum, quite a little blood was lost before it was clamped and tied. This was the only untoward feature of the operation. There was firm fibrous union at the site of the former resection of the tibia (Fig 24), but the fragments could be moved just enough upon each other by the hands to make the motion visible. The periosteum was reflected, the bone divided along the former sections, and the ends delivered. The fragments were sawed as indicated in Figure 27C, and it was necessary to resect the fibula to allow apposition of the ends of the tibia in the correct axis. The tibial fragments were encircled by one Parham band, which gave perfectly firm fixation (though no indiscrete attempts were made to try its strength). To keep the band from slipping down the conical surface of

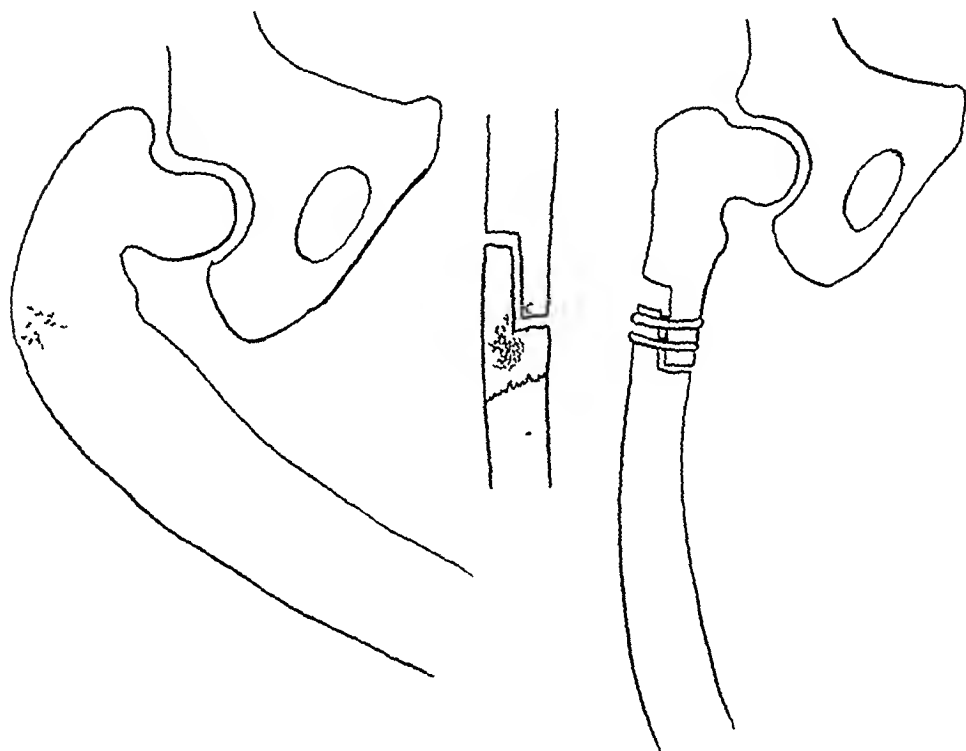


Fig 26—Right femur resection, with fixation by Parham bands

the tibia, a groove was cut in the crest of the bone, in which the band was fitted. The wound was closed, and a plaster-of-Paris dressing was applied from the toes to the groin. The operation lasted an hour, and the patient was distinctly shocked. But as his pulse had always risen to 160 at the end of the previous operations, no undue alarm was felt at the conclusion of this. He was given stimulation, put to bed with local heat, a hot enema was administered, and the foot of the bed raised, but he failed to react, and died about an hour after the end of the operation. Failure to appreciate the cumulative effect of five major operations in the course of six months, perhaps with the little extra bleeding and delay occasioned by injury of the long saphenous vein, seems to have been the cause of the fatal termination.

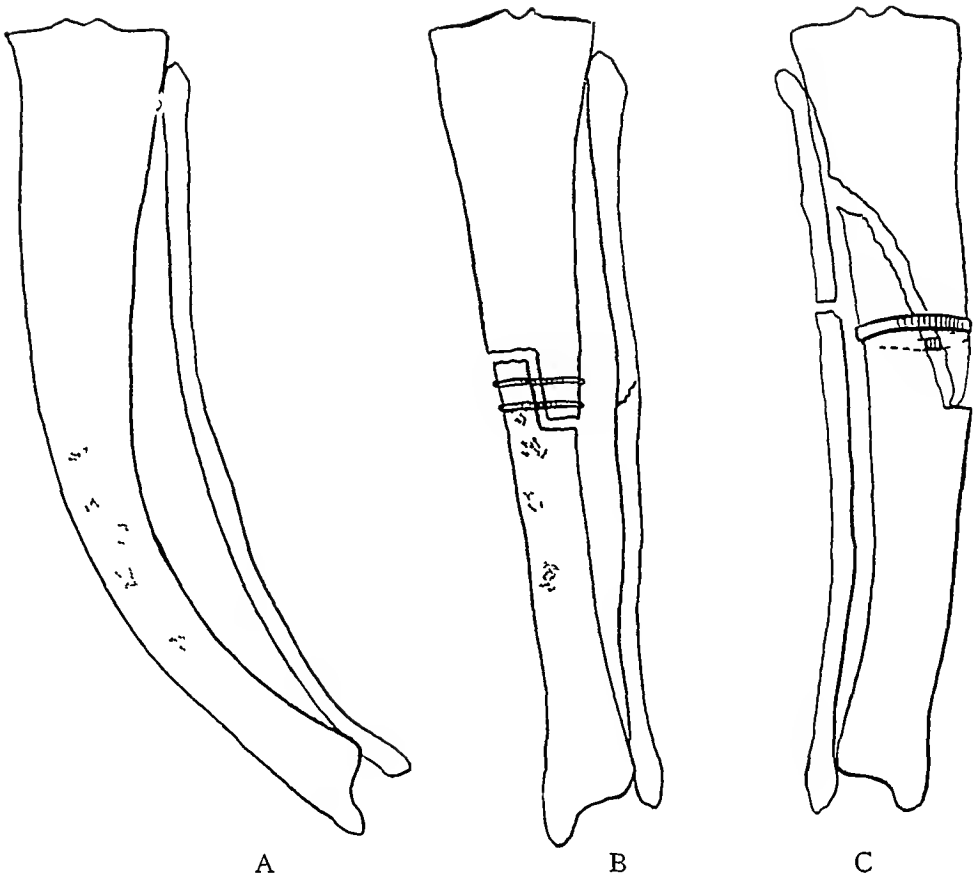


Fig 27—*A*, left leg, *B*, resection of tibia, with fixation by Parham bands, *C*, right leg, second resection, with fixation by one Parham band

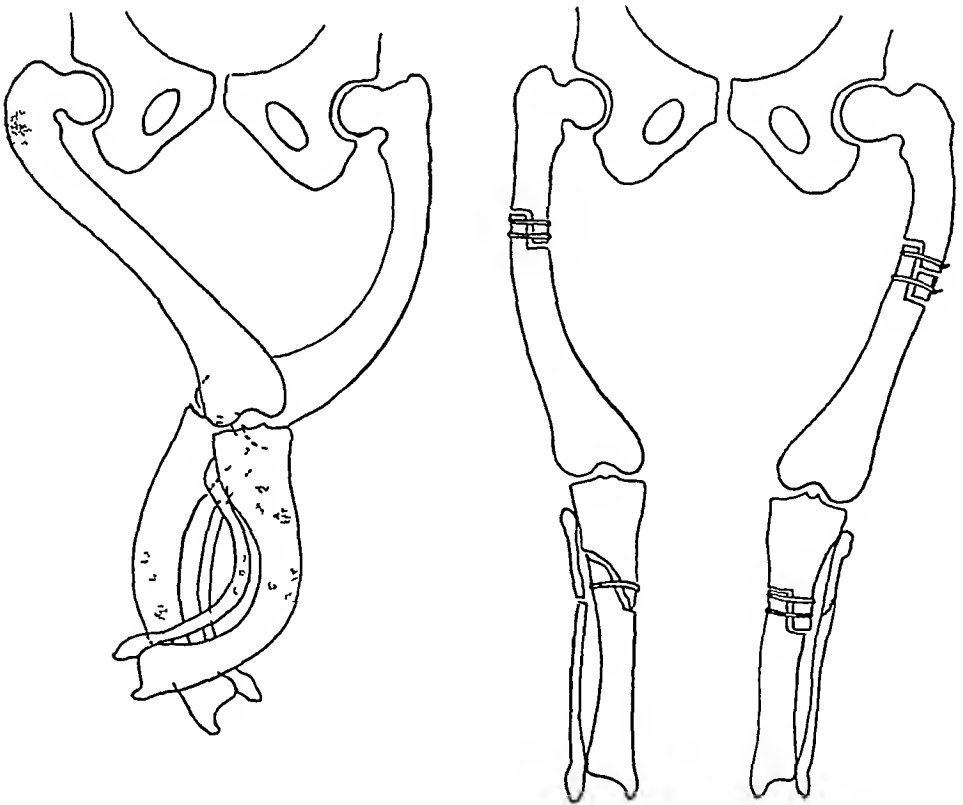


Fig 28—Lower limbs before any operations and after last (fifth) operation

*Pathologic Report* (Dr C Y White) —The findings revealed typical osteitis fibrosa. Between spicules of bone, the sections examined were made up of loose fibrous tissue, with fully formed capillaries and larger blood vessels. The bone stained more deeply than the normal in areas, and were more cellular than normal—apparently undergoing absorption. No giant cells were seen.



Fig 29 (Case 9) —Cystic osteitis of the left humerus

*Metabolic Studies* —While the patient was in the Orthopaedic Hospital metabolic studies, made by Dr E P Corson White, indicated an excessive loss in the excreta of calcium and phosphorus. Dr White believed that the disease was of the osteomalacia type.

CASE 9—*Myeloma (giant cell sarcoma) of the humerus* History—S B, a brunette girl, aged 13, was admitted to the Episcopal Hospital Nov 11, 1920 In November, 1919, a tonsillectomy had been performed

In 1916 she fell and bruised the left arm It became swollen and her mother rubbed it with liniment The swelling soon subsided and she had no further trouble, but she said that "if any one frightened her after this her arm became numb and she was unable to move it at the shoulder" She had injured the arm several times since 1916, and each time it became swollen, but the swelling always subsided in a few days

Aug 1, 1917, she was treated in the surgical dispensary of this hospital for an injury of her left arm, for which liniment was prescribed

Nov 8, 1920 she fell downstairs, striking her left shoulder, and was unable to lift it She came to the surgical dispensary where she was seen by Dr W R



Fig 30 (Case 9)—Diagram showing nature of operation employed

Brown, Jr, who, after having the arm roentgenographed, referred her to the service of one of us (A P C A)

Examination—She was a well developed stout Jewish girl, normal except for the condition of the left arm, which was somewhat swollen from the shoulder almost to the elbow and felt slightly hot to the touch The bone was thickened There were a false point of motion and crepitus about the middle of the humerus She was unable to use the arm

Roentgen-Ray Report (Dr R S Bromer, Fig 29) 'Upper half of left humerus shows marked cystic formation This does not resemble one huge bone cyst but has the typical appearance of cystic osteitis There is a pathologic fracture of the shaft of the humerus' Dr Ashhurst "Roentgen ray shows cystic expansion of upper part of humerus as far down as insertion of deltoid to more than twice its normal diameter The expansion is not abrupt at the

lower limit of disease, and extends up to the epiphyseal cartilage of the head, which is still visible. There are numerous trabeculae in the cystic area and a transverse fracture through the middle of the cyst, without displacement."

*Operation*—Nov 16, 1920, Esmarch anemia was secured by the use of a rubber bandage around the shoulder, held in place with Wyeth's pins, as in cases of amputation at the shoulder joint (compare operation in Case 6)

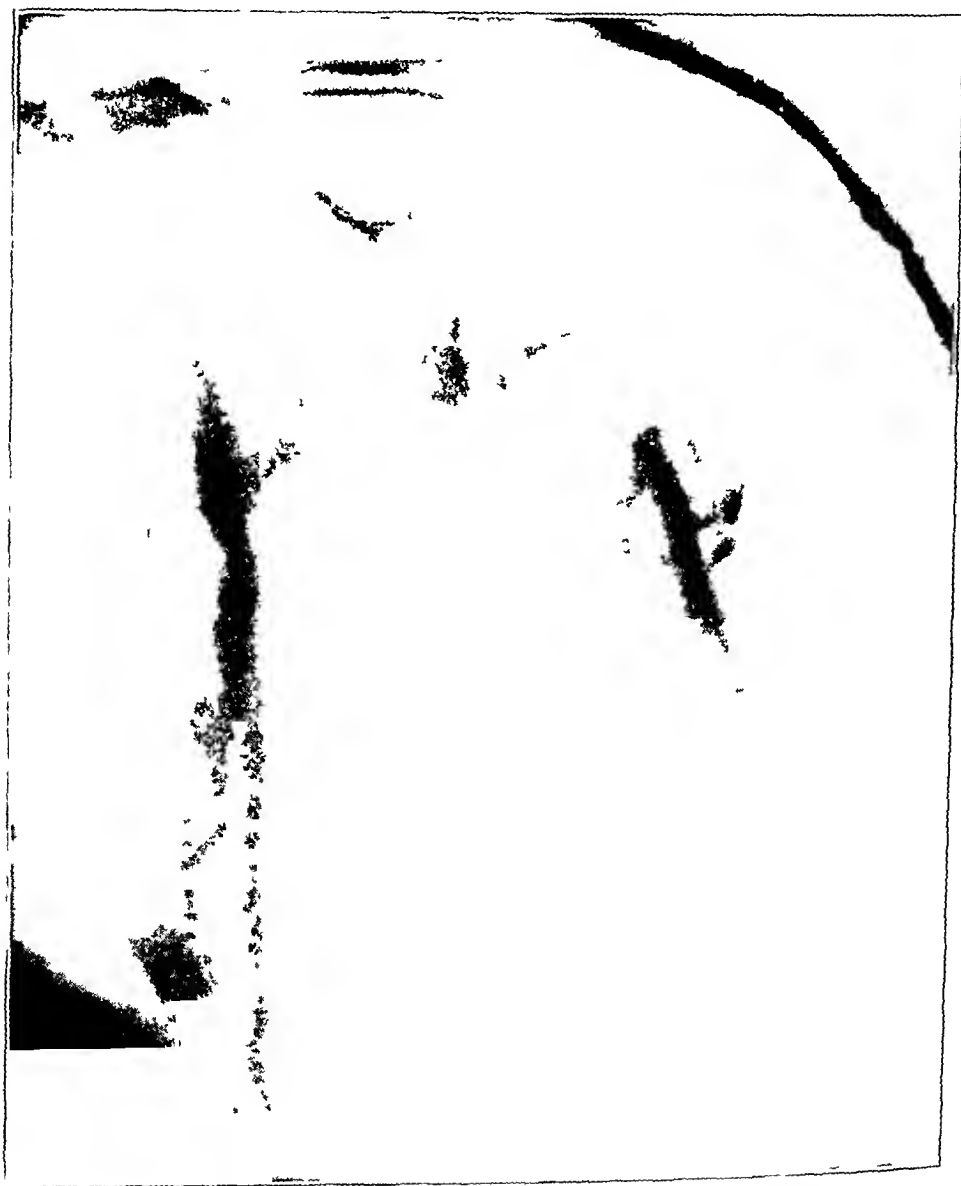


Fig 31 (Case 9) —Left humerus, fifteen weeks after operation

An incision was made, 20 cm in length, from the greater tuberosity of the humerus downward, just laterad to the biceps muscle. When the periosteum was reflected from the bony prominence, a subperiosteal fracture was disclosed at the middle of the bony swelling. The cortex of the humerus was almost deficient at this point and was easily perforated by a periosteal elevator. When

opened it was found to be only 1 mm thick. Inside the cyst were several bony trabeculae, incompletely dividing it into the different cavities. The contents of the cyst consisted mostly of yellow, slightly turbid fluid, with a little currant jelly like tissue. A culture was taken, and this, as well as specimens of the



Fig 32 (Case 9) —Left humerus, nine months after operation

bone marrow and cortex was sent to the laboratory. The marrow cavity was thoroughly cleared out with the curet as far as the epiphyseal cartilage above, and downward to the point where the cortex and marrow appeared normal, although even here the marrow appeared grayish and congested.

An aperiosteal transplant was then cut from the subcutaneous surface of the left tibia, 15 by 125 by 125 cm, and was fitted snugly into the interior of the cyst, a slot being cut in the shaft distal to the cyst, in order to admit the transplant without disturbing the fragments of the humerus (Fig 30). The cyst walls were then crushed in, considerably diminishing the size of the cavity. After complete closure of the soft parts in layers, the Esmarch bandage was removed, and the entire upper extremity and thorax encased in plaster of Paris, with the shoulder abducted about 45 degrees.

*Laboratory Report* (Dr C Y White) —The fluid from the tumor was sero-sanguineous. An unstained film showed nothing pathologic. A stained film showed the usual red and white cell elements, with slight excess of lymphocytes. Culture of the fluid showed it to be sterile.

*Microscopic* Sections of fragments of tissue submitted were made up of (1) fibrous tissue similar in every respect to scar tissue which bordered a small section of bone, (2) larger spicules of bone undergoing absorption. Surrounding the bony spicules were areas of hemorrhage. In their immediate vicinity were a few giant cells (epulis type).

*Diagnosis* This was fibrocystic osteitis with giant cells.

*Course* —Nov 23, 1920, a slight continuous fever had been present since operation, from 99 to 101 F. The temperature was normal today. The patient sat up in a chair all day.

November 26, the leg wound was dressed. The incision was healed.

December 11, she was put back to bed because of fever (101 F), and a purgative was given.

December 17, the temperature was normal. The patient was out of bed.

December 22, she walked about the ward.

Jan 7, 1921, seven weeks after operation, the case was removed from the arm and chest, and the first dressing was made. All skin sutures were infected. No deep infection was apparent. Union was firm in the humerus. A new cast was applied to the arm and chest, and the patient was discharged from the ward the next day.

March 4, 1921. The arm had been dressed weekly since the last note through a window in the cast. Healing was complete, except for a small granulating area at the upper end of the incision. The cast was removed today and a shoulder cap of gypsum was applied. There was firm union and no deformity. The roentgen ray (Fig 31) revealed the bone much denser and less expansion. The transplant was intact, there was no deformity.

Aug 1, 1921, a sinus had persisted. Recently a small sequestrum was discharged spontaneously. As there was no disability and the girl was able to use her arm normally, the parents declined any radical treatment for cure of the sinus. A roentgenogram (Fig 32) showed the transplant absorbed and the humerus to be of nearly normal density.

June, 1922. The sinus healed in September, 1921, and had remained closed. There was no disability.

*CASE 10—Myeloma (giant cell sarcoma) of the lumbar vertebrae*<sup>13</sup> *History*—O N, a brunette boy, aged 14 years, was admitted to the Orthopaedic Hospital, Dec 28, 1913. Oct 13, 1913, he had strained his back by lifting one end of a 300 pound elevator weight. That night he suffered severe pain in

<sup>13</sup> This case has already been the subject of a report by Dr G B Dent (Ann Surg 62 636, 1915).

the back, radiating from the lumbar region to the right hip. In several days the pain ceased. One month later, while playing at school, he was knocked down and fell against a stone wall, striking the right lumbar region. This caused so much pain that he was taken home and put to bed. After being in bed for a time he got about on crutches, but, Dec 1, 1913 he was taken to a hospital in his home city and treated for rheumatic arthritis of the right hip.



Fig 33 (Case 10) —Roentgenogram, one month after operation of a myeloma involving the right side of the lumbar vertebrae

He was transferred thence to the Orthopaedic Hospital, four weeks later, with the diagnosis of "progressive muscular atrophy."

*Lamination*—On admission he was suffering with severe pain in the right lower quadrant of the abdomen and in the right hip. This pain was paroxysmal in character, lasting an hour or more at a time. He was a fairly well



nourished boy and about the average size for his age. In the right lumbar region was a large mass, semisolid in consistency, occupying the entire right lumbar region and the right lower quadrant of the abdomen. This mass was extremely tender on palpation. The knee jerks were increased, and there was bilateral ankle clonus.

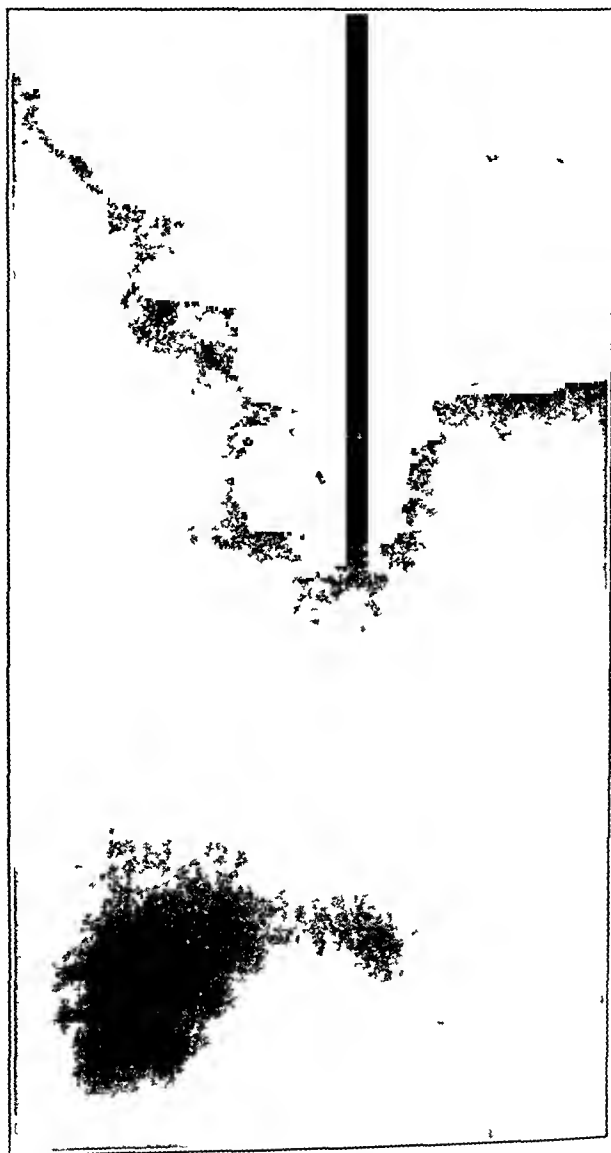


Fig. 34 (Case 10)—Appearance of vertebrae, five months after operation.

Two days after admission, the temperature was 101.6 F, having varied between 99 and 100 F ever since admission. The leukocytes numbered 9,000, the urine was negative. The boy had had several severe attacks of pain in the right loin, writhing, moaning and jerking the limbs during these attacks. He lay either prone, or on the right side, always with the right hip flexed. Today there was no ankle clonus, and the knee jerks were absent on both sides. He complained of much referred pain in the right knee. The mass in the loin

remained about the same as on admission, but anteriorly it could be more clearly outlined, extending from the costal border to below the level of the umbilicus. The right iliac fossa was free, and the lower edge of the mass was easily outlined above it. The mass did not move in respiration and was quite fixed on palpation and moderately tender. It was continuous with the liver dulness. Roentgen-ray examination of the spine was negative.

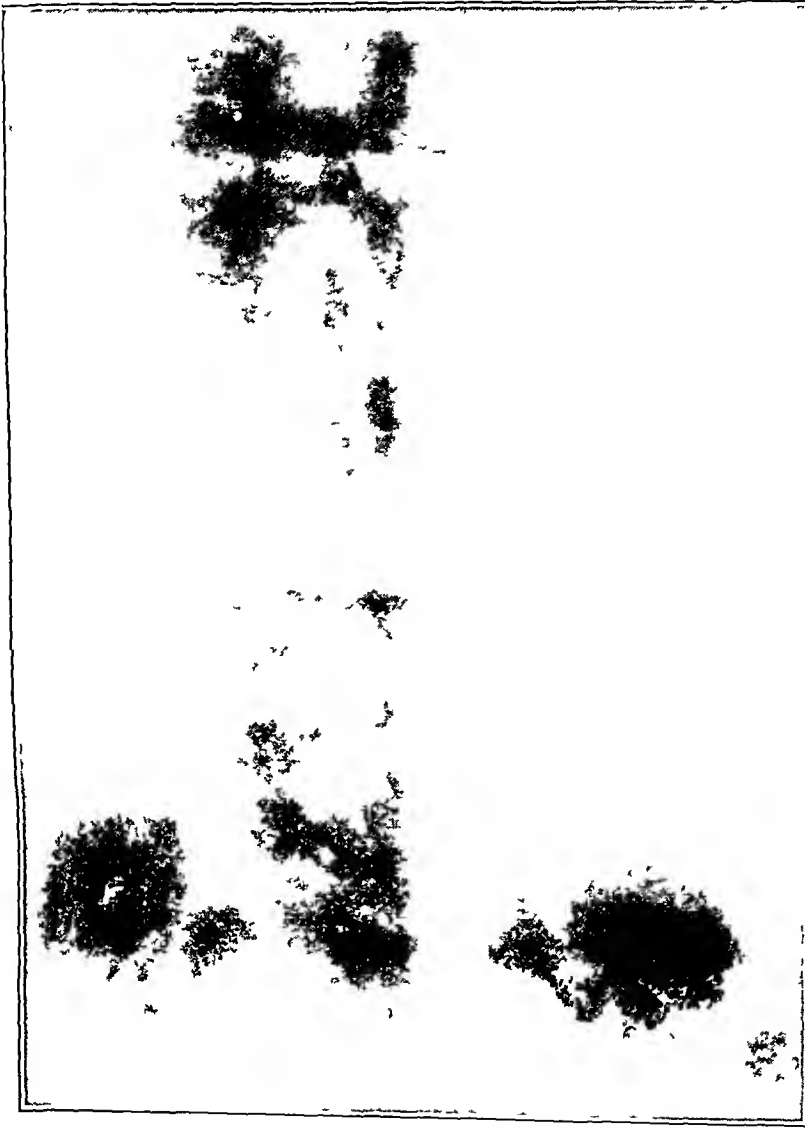


Fig 35 (Case 10) —Vertebrae, seventeen months after operation

The preoperative diagnosis was (1) probably a cold abscess, though it was considered very unusual for such a lesion to be outlined so clearly and so firm as this tumor, or for an abscess of this size to form within so short a time (two and one-half months) and without demonstrable lesion of the spine, (2) perhaps a hypernephroma or sarcoma, but it was thought that the spinal cord symptoms favored the diagnosis of cold abscess.

*Operation*—Under ether anesthesia operation was performed Dec 30, 1913. After incising the lumbar fascia through an 8 cm incision in the right loin, a well encapsulated bluish tumor was exposed, easily outlined below and in front. It was shaped like the lower pole of the kidney, but was much larger, and not quite so firm in consistency. When the capsule was punctured there was a gush of semiclotting blood, about 500 cc, mostly fluid being evacuated. The lumbar and sacro-iliac joints could be palpated apparently free from all muscular attachments, but there was no area palpable which seemed to be devoid of periosteum. Two of the transverse processes of the lumbar vertebrae felt bare, and the erector spinae muscle seemed destroyed. Fragments of tissue (muscle? tumor? angiosarcoma?) were saved for examination. The rather profuse hemorrhage stopped after complete evacuation of the diseased tissue, the cavity was packed with iodoform gauze around a

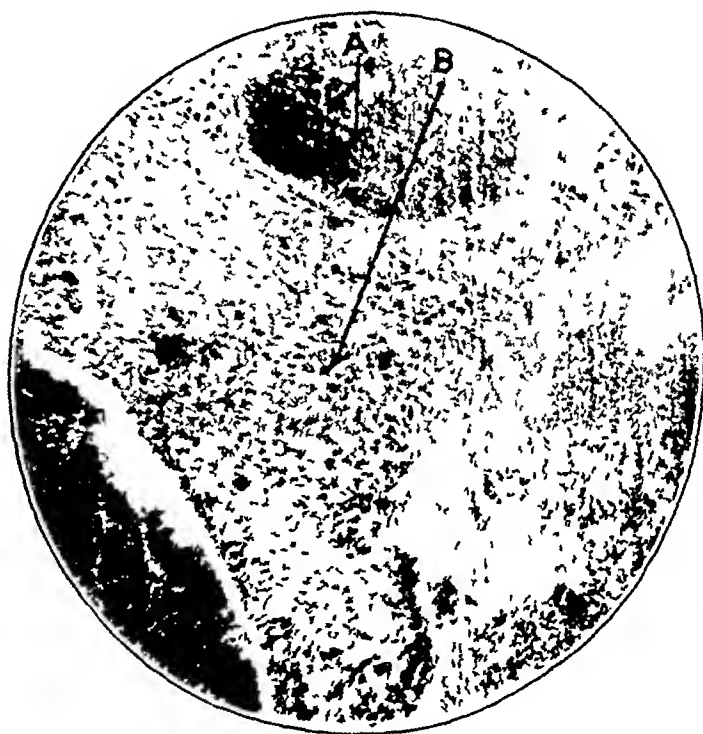


Fig 36 (Case 10)—Low power photomicrograph of tissue secured at operation. *A*, blood clot, *B*, tumor tissue.

rubber tube, and the wound was closed in layers. The gauze and tube were removed during the first week.

*Pathologic Report*—One specimen of the tumor was examined by Dr E P Corson White, pathologist to the Orthopaedic Hospital, and another section by Dr C Y White, director of the laboratories of the Episcopal Hospital. The report from both laboratories was that the tumor was a "giant cell sarcoma" (Figs 36 and 37).

*Course*—As the swelling in the loin began to reappear during the third week after operation, treatment with Coley's fluid (mixed toxins of streptococcus and *Bacillus prodigiosus*, supplied by Dr Martha Tracey) was begun. A roentgenogram taken one month after operation (Fig 33) showed a moderately dense

and irregular shadow in the right loin, extending from the third, fourth and fifth lumbar vertebrae to the crest of the ilium

Jan 22, 1914, three weeks after operation, the first injection of Coley's fluid (1/10 minim) was given into the buttocks. Seventeen weeks after the initial dose, the amount administered had been gradually increased until 42 minims were being given. At no time during these weeks were the reactions severe. After an interval of three weeks, during which no Coley's fluid was given, injections were resumed, the first dose being 42 minims, the amount being gradually increased until 48 minims had been reached. Again an interval of rest for three weeks was allowed, after which the injections were resumed, beginning with a dose of 48 minims. From this time on the reactions were rather severe, the temperature often rising to above 102 F and at times reaching 103.2 F. Chills accompanied the temperature, and there was always severe pain at the site of

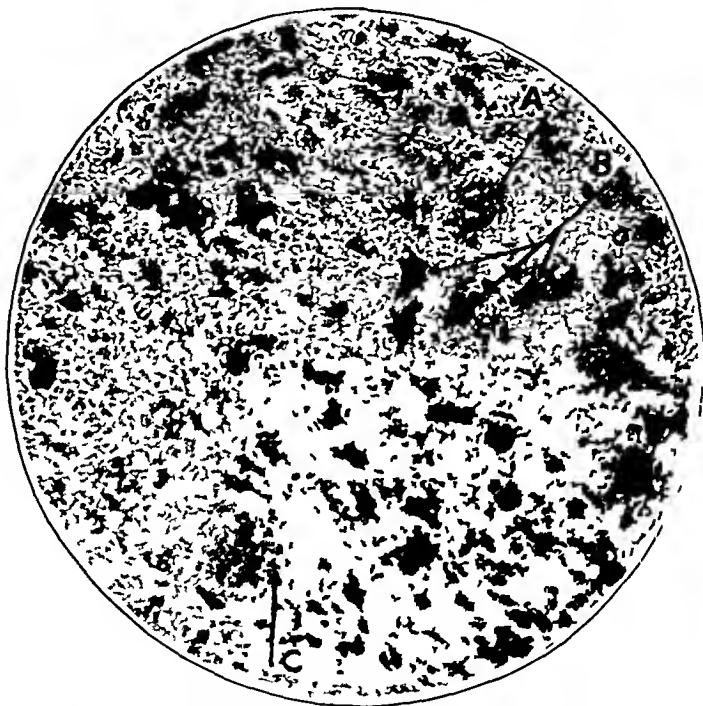


Fig 37 (Case 10) —High power photomicrograph of tissue secured at operation. *A*, giant cell, *B*, blood pigment, *C*, giant cell

the needle puncture and often marked skin reactions. The highest dose reached was 56 minims. At first, as already stated, the injections were made in the buttocks first on one side, then on the other, gradually approaching the site of the tumor, until finally the injections were given directly into the tumor in the loin. These injections were continued over a period of eight months, with only two periods of rest of three weeks each. During these intervals the patient's general condition improved a great deal. The injections were never given on two successive days, but two or three times weekly. Morphine, codeine or acetylsalicylic acid (aspirin) was frequently required for pain, but though tonics were required, the lad's state never became so bad as to require stimulation. The reactions on the whole were very mild, but occasionally very

severe Dr Denit, in his original report, states that in a letter received from Dr Martha Tracey, Philadelphia, whose preparation of Dr Coley's toxins was used, she stated that the highest dosage employed by Dr Coley was 26 minims, though she knew of one case in which 30 minims was given at a dose Dr Denit believed that the dosage reached in the case now reported, 56 minims, was the highest yet reported

The tumor, which, after the operation wound had healed, had begun to increase in size (Fig 34), remained about the same in consistency until the end of September, at which time it began to become softer and to increase markedly in size Several days later the mass broke down and discharged through the scar of operation in the loin From this time the mass diminished



Fig 38 (Case 11) —Myeloma involving the head of the tibia

in size and became harder in consistency until at the time the injections were discontinued, it had the consistency of a bony tumor This tumor seemed to be adjacent to the fourth and fifth lumbar vertebrae in the right loin

The patient was discharged, Nov 10, 1914 He had been up and about the ward almost daily since early in February, about two weeks after the administration of Coley's fluid was begun, when the pain had almost subsided On discharge, no tumor could be palpated through the abdominal wall, and the mass in the loin had decreased markedly in size and assumed the form of a bony tumor At this time the patient's weight was  $76\frac{1}{2}$  pounds (35.4 kg) Six months later it was 103 pounds (47 kg) He appeared to be in perfect health and there was no increase in the size of the bony tumor, which appeared as a dense bony mass in the roentgenogram (Fig 35)

In August, 1920, nearly seven years after operation, he was reported as being in good health. He had served through the war without disability, but he had had the misfortune to lose an eye.

CASE 11—*Myeloma of head of left tibia* History—Lieut J D, U S A, brunette, aged 23, was under my care at the Walter Reed General Hospital, Washington, D C, in April, 1919. Nine years previously, when 14 years of

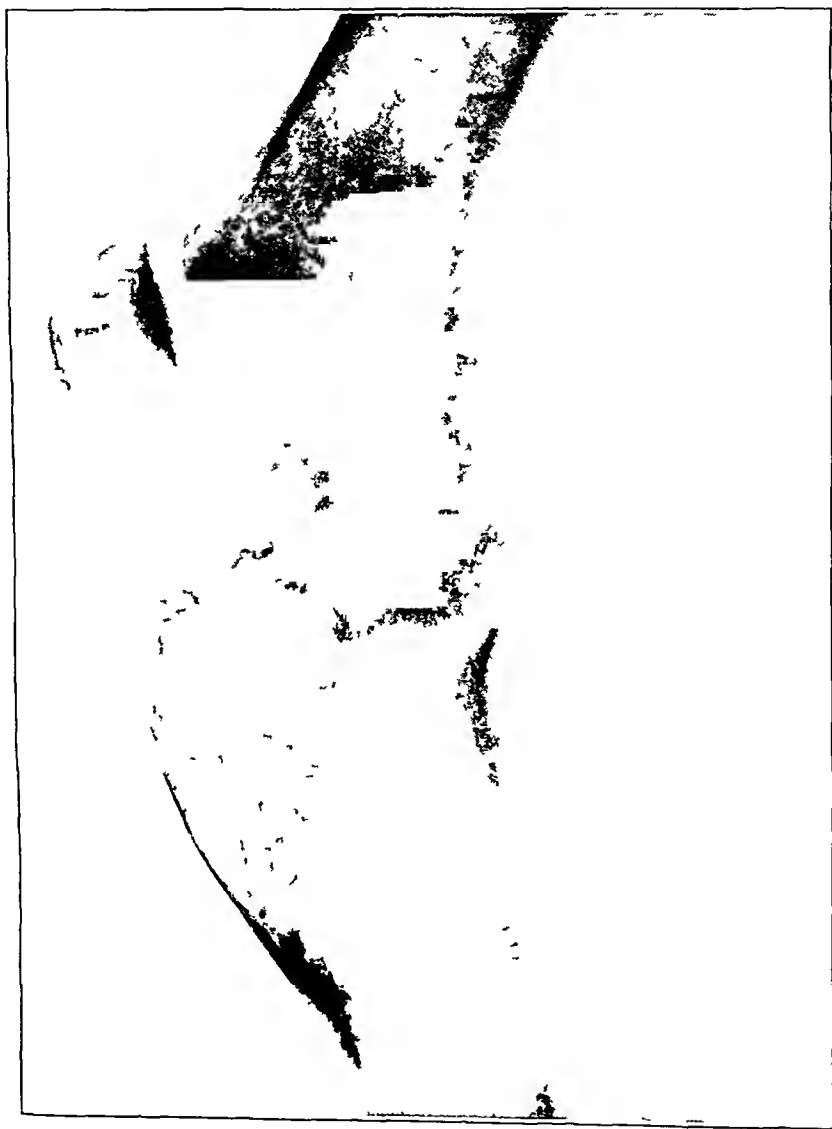


Fig 39 (Case 11) —Myeloma involving the head of the tibia, duration nine years

age he received a violent blow below the left knee from a heavy piece of wood. He was in so much pain that he was unable to walk for an hour and a half. He then hobbled home. Within a few months, a bony lump made its appearance but caused no disability. It grew slowly larger for several years, but he was convinced that it had grown no larger during the last five years,

as he was able still to wear the same pair of tight fitting knee breeches that he had made five years previously

*Examination*—There was a visible mass bulging on both sides of the crest of the tibia at its head, the crest also bulged forward. The appearance was similar to that of the normal knee joint, but palpation demonstrated the real knee joint, which looked like the thigh, entirely above the area where the bony tumor existed in the head of the tibia (Fig 38). Roentgenograms, made by Major Selby, showed the typical trabeculated appearance of a myeloma (Fig 39). On account of the patient's age, which made the presence of sarcomatous changes more likely than in a child, and because of the persistence

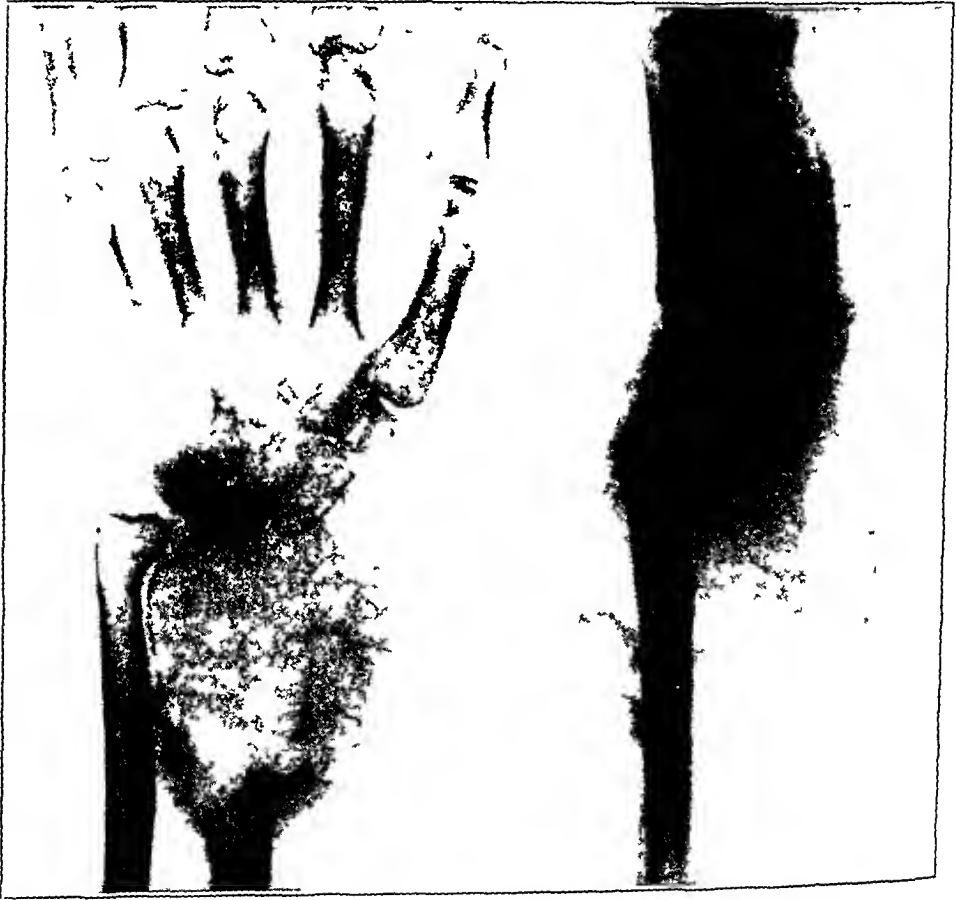


Fig 40 (Case 12)—Myeloma involving the lower end of the radius, just before first operation, Feb 20, 1913

of the tumor, operation was urged, that the true diagnosis might be ascertained and an intelligent prognosis furnished to his commanding officer. The patient being desirous of remaining permanently in the army.

*Operation*—April 14, 1919, under Esmarch anemia, the cortex was removed over the median and lateral aspects of the head of the tibia, leaving the crest and tuberosity intact. The lateral surface was bosselated, and the periosteum was very adherent. There was no fibrous lining to the cyst, which was multilocular and contained some yellow fluid, tissue resembling currant jelly and

softened bone. The interior was cleared out by gouge and curet until normal bone was reached in all directions. The sides and anterior wall, except the crest, were then crushed in, partially filling the cavity. The periosteum, fascia and skin were closed in separate layers before removal of the Esmarch bandage and a plaster-of-Paris dressing was applied.

*Pathologic Report*—This appears to refer only to a specimen of the cortex removed. "Absence of lacunae and osteoblasts, no evidence of inflammatory reaction, bone sclerosis."



Fig. 41 (Case 12)—Radius, seven months after first operation

*Course*—In July, 1919, after my return to Philadelphia, he wrote me that he was walking all he wanted with crutches but with no disability.

In September, 1919, he visited my office still using a cane, as his leg felt a little weak. He was not able to run. The right tibia measured 29.5 cm below the knee, the left 32 cm. Recent roentgenograms showed normal bone throughout the head of the tibia.

In September, 1921, he wrote that only a small lump of bone remained (this was the protruding tibial crest not crushed in at operation) and that he had



no disability whatever, except that sometimes in damp weather or after a very strenuous day's work, he was conscious of a little "rheumatism" in the leg

In March, 1923, he confirmed the last report in person

**CASE 12—Myeloma of radius, recurrence after curettage, excision and transplantation of bone** *History*—S M, a brunette woman, aged 22, applied to Dr Harte's service at the Orthopaedic Hospital, Feb 20, 1913, with a cystic swelling of the wrist, which at first sight was mistaken for tuberculosis of the tendon sheaths. The swelling had gradually developed during the preceding year (since February, 1912) from no well ascertained cause. A roentgenogram (Fig 40) showed the lower end of the radius destroyed by a cyst, which, however, left the wrist joint and the overlying soft parts intact. March 5, 1913, Dr Harte opened and curetted the cyst, whose walls were very thin, there being scarcely any trace of bony tissue discernible.<sup>14</sup> A transplant was cut from the tibia and inserted in the interior of the cyst to maintain the form of the bone and in the hope of stimulating osteogenesis. For months the local condition continued



Fig 42 (Case 12)—Radius, fifteen months after first operation, showing recurrence just before second operation, June 1914

to improve. The tumor became smaller and its walls firmer, it lost its cystic feel, but the forearm remained abnormally large and caused the patient considerable annoyance. A roentgenogram taken Sept 24, 1913, six months after operation, showed that the transplant was being absorbed (Fig 41). Early in 1914 the tumor again began to soften (Figs 42 and 43), the local heat and discomfort increased, until finally in June, 1914, the girl consented to another operation. She was referred to my service at the Episcopal Hospital.

*Operation*—June 27, 1914, I excised the entire lower end of the radius, including its periosteum and articular surface. It was found that the extensor tendons of the thumb passed through a canal in the tumor, and while one of the tendons could be pulled out of this canal after being divided, the other could not be extracted and about 2 inches of it had to be removed with the tumor. Moreover, the tumor so overhung the carpal bones, although it had not broken

<sup>14</sup> Dr Paul A Lewis, then of the Pennsylvania Hospital, reported that the growth was a "giant cell sarcoma."

through the articular surface of the radius, that it was impossible during the operation to outline its limits precisely, and the scaphoid and semilunar bones were inadvertently removed along with the tumor. A transplant, with periosteum attached was then cut from the tibia (5 inches long, and of the thickness and shape of the lower end of the radius) and inserted in the large wound caused by removal of the tumor. This transplant was fixed to the shaft of the



Fig. 43 (Case 12)—Myeloma of radius, just before the second operation, June, 1914

radius by a steel plate, the plate was screwed to the radius, but as the screws fixing it to the transplant twisted loose when half inserted, it was necessary to fix the plate to the transplant by a wire loop (Fig. 44). In Figures 45 and 46 the operative specimen is illustrated. Healing was uneventful. A splint was worn for three months after the operation. At that time the transplant was firmly united to the shaft of the radius; there was rotation in the forearm through an arc of more than 90 degrees, there was flexion in the wrist to 140

degrees, and extension to a straight line (180 degrees) The patient could make a good fist, and had fair power of grasping, which was rapidly improving Figure 47 is from photographs made three months after operation

*Course*—In December, 1921, seven and one-half years after operation, there was normal strength, and the patient found the hand perfectly useful in her trade of cigaret maker



Fig 44 (Case 12) —After operation, June, 1914

Feb 12, 1922, she struck the dorsal surface of the right wrist against a table It pained her all night, but after that she had no symptoms until February 21, when she began to have pain in the thumb and index finger Examination February 24, showed tenderness and slight warmth and possible false motion about the middle of the transplant, about 5 cm above the wrist joint The roentgen ray revealed fracture of the transplant through the site of the most distal screw holding the plate

*Second Operation*—March 11, 1922, operation was performed to remove the bone plate and the screws, and to investigate the site of fracture (Orthopaedic Hospital) Incision was made, excising the scar of the operation of June, 1914, about 15 cm long, from the base of the thumb metacarpal upward This was deepened to bone in front of the flexor carpi radialis The fascia and muscles surrounding the steel plate inserted eight years previously were stained black A fracture was found, nearly transverse and subperiosteal, involving the transplant at the site of the distal screw (Fig 48) This screw had twisted off while

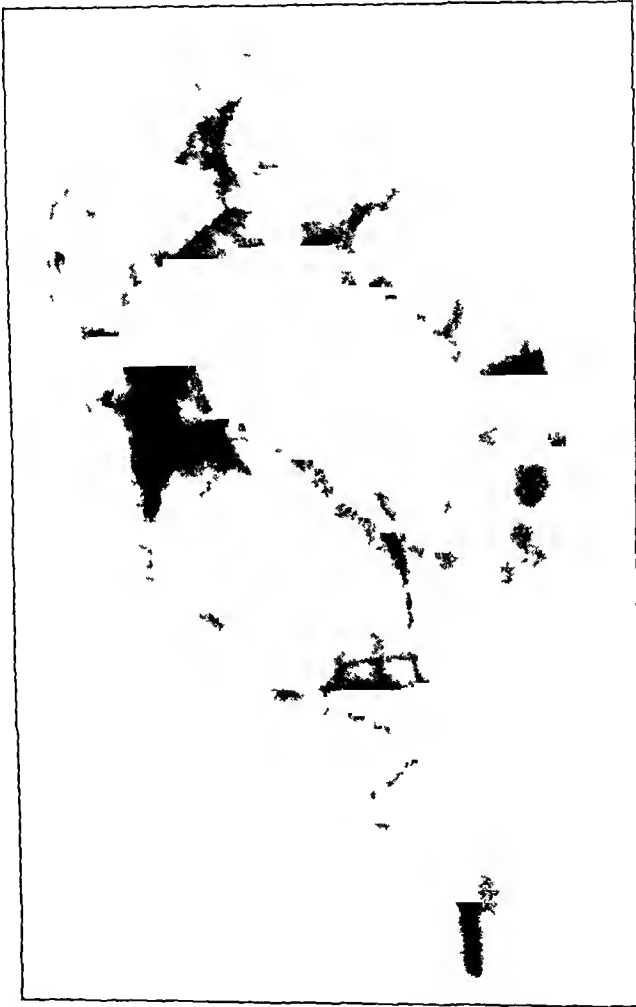


Fig 45 (Case 12) —Roentgenogram of specimen removed at operation

being inserted at the previous operation, and while buried in the bone did not project into the corresponding screw hole of the plate The most proximal screw (in the original shaft of the radius) was still firmly fixed in the bone, and had to be unscrewed almost to its tip before removal The second screw (also in the original shaft of radius) was loose, as was the third screw (in the proximal end of the transplant), but the screw at the site of the recent fracture was so densely embedded in the bone of the transplant that it could be removed only by gouging out the bone all around it The distal encircling wire was easily

broken, but the proximal wire (Fig 48) had to be cut. In both, the twisted ends were intact. The fracture occurred through bone, apparently dead, white, avascular and very dense, but perfectly continuous with the surrounding well vascularized bone of the transplant, which extended to within less than 1 cm of each side of the fracture. The plate, screws and wires were removed. The junction of the transplant with the shaft could not be identified. The projecting extensor surface of the distal end of the transplant at the wrist was cut down level with the surrounding bone, and the fragments of bone thus secured were placed between the fractured ends of the transplant, after each fractured end had been gouged out until vascular bone was reached. Specimens of dead and living bone (in one piece) were saved for laboratory examination.<sup>15</sup> The extensor tendons of the thumb exposed above the wrist were normal but adherent to each other, and with some scar tissue around them. (Compare description of previous operation.) The wound was closed in layers with

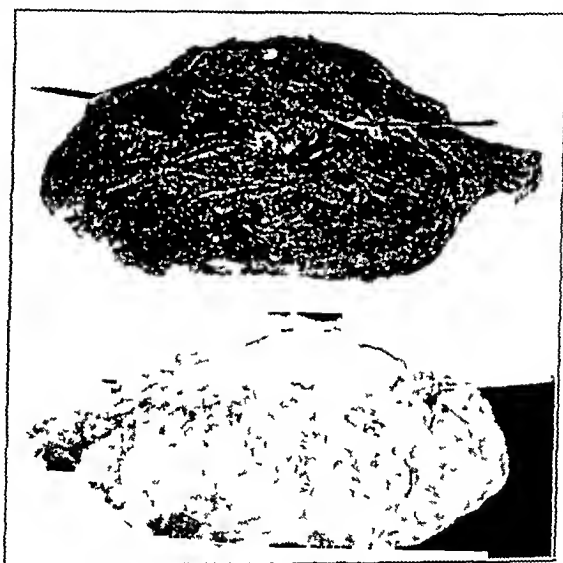


Fig 46 (Case 12)—Specimen removed at operation. Above, the extensor surface of the specimen, with a probe passed through the canal occupied by the extensor tendons of the thumb; below, appearance of flexor surface, the ulnar aspect resting on the table.

chromic catgut, and an internal angular splint was applied. Figure 49 is from a roentgenogram made four weeks after this operation.

In December, 1922, nine months after the last operation, there was not yet bony union in the fractured transplant, but the patient had been at her usual work for some months.

In February, 1923, for continued nonunion, an aperiosteal bone transplant from the tibia was inlaid across the site of fracture. Firm union was then secured. Pathologic examination of the larger pieces of bone removed from the site of fracture at this time (Dr. E. P. Corson White) showed no evidence of tumor, only sclerosed bone.

<sup>15</sup> Examination by Dr. E. P. Corson White, pathologist to the Orthopaedic Hospital, convinced her there was dead bone present, and also areas of "giant cell sarcoma."

*Pathologic Report* (Dr C Y White)—On section of tissue received from Dr E P Corson White, removed at operation in 1913 (Figs 50 and 51), the report was that the general structure of the tumor mass was peculiar in that it consisted almost entirely of "epulis" giant cells, with nuclei varying in number from four or five to twenty or thirty. Between these giant cells were a few large cells with vesicular nuclei, a few small lymphocytes, a very few blood vessels (fully formed), and elsewhere blood which seemed to be either hemorrhage or blood which was coursing in spaces between cells (with no blood vessel walls). There were undoubted fat cells throughout the tissue. The stroma (intercellular substance) of the mass seemed to be very small in amount.

One border of the section showed very few giant cells and numerous spindle cells, arranged somewhat in whorls. There were limited areas, showing the latter type of cells, which suggested spindle cell sarcoma.

Throughout the entire section there was some evidence of karyokinesis.

Diagnosis (June 9, 1922) Giant cell sarcoma (of epulis type) with beginning malignancy (spindle cell sarcoma).<sup>16</sup>



Fig 47 (Case 12) —Appearance of arm, three months after operation

*Pathologic Report* (Dr C Y White, June 9, 1922)—On tissue (Fig 52) from second operation, June, 1914, the report was that the tumor consisted of spindle cells not densely packed, fully formed blood vessels, and, enmeshed in the stroma, rather numerous typical giant cells (epulis type). Elsewhere in the section was fully formed fibrous tissue. The whole picture was one of chronic granulation tissue with giant cells.

The arrangement of the spindle cells showed a distinct tendency to formation of whorls. In areas there were small capillaries with normal walls as well as a few larger blood vessels. Throughout the tissue were numbers of large "gigantic cells."

In comparison with the tissue from the specimen removed in 1913, there were not one tenth as many giant cells (epulis type). The spindle cell was the prevailing type of cell, suggesting sarcoma. It was much more like sarcoma.

<sup>16</sup> Dr W H F Addison, professor of histology and embryology in the University of Pennsylvania, ventured the opinion that the giant cells in this section (Figs 50 and 51) resembled megalokaryocytes rather than foreign body giant cells, but as they represent a pathologic and not a normal constituent of bone, he hesitated to differ too positively from experienced pathologists.

than the 1913 tissue. Against sarcoma was the presence in the 1914 sections of well formed blood vessels, both capillary and larger vessels.

**Diagnosis** The question as to whether it was to be regarded as chronic granulation tissue with giant cell formation, or chronic granulation tissue with sarcoma formation, was debatable, but the latter diagnosis was favored.<sup>17</sup>

**CASE 13—Myeloid sarcoma of humerus** *History*—J W, brunette man, aged 37 years, was admitted to the Episcopal Hospital Jan 19, 1921. The patient was a carpenter. Two years previously he began to experience soreness in the right arm. He rubbed it with liniments and painted it with iodine. Pain was present only when he lifted the arm over his head and when he did heavy work. More than a year previously when he was throwing ashes out of a cellar window, his right arm broke. He went to the University Hospital where a roentgenogram was taken<sup>18</sup> and where he was treated. He was out of work for five weeks, but even after return to work the soreness in the arm and pain during hard work continued. This disability had been growing worse during the last two months.

Ten days previously, while helping his wife pull out a bureau drawer, he noticed a crack in his arm, and was disabled with pain on the slightest motion. He came to the dispensary of this hospital for treatment, where he was under the care of Dr William Whitaker. Roentgenograms made by Dr R S Bromer, Jan 12, 1921 showed "a condition which involves the upper third of the humerus, resembling very much a chronic cystic osteitis, with a pathologic fracture at the junction of the middle and upper thirds of the shaft" (Fig 53).

*Examination*—The patient was admitted to the ward, one week later. He was a stout, healthy looking individual, appearing older than his given age. The right arm presented slight palpable bony thickening in the upper third of the humerus, no redness, only slight tenderness on palpation, preternatural mobility and crepitus at the junction of the upper and middle thirds, and no apparent deformity.

**Diagnosis** This was cystic osteitis, probably benign, possibly sarcomatous since at this patient's age purely benign cysts are unusual.

*Operation*—Jan 21, 1921, an incision was made from midway between the acromion and coracoid, downward along the lateral border of the biceps to the

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17 These slides were also examined by the following pathologists, whose opinions are appended: Dr Allen J Smith, Philadelphia giant cell sarcoma, locally malignant; Dr John Speese, Philadelphia giant cell tumor, more malignant than sections in 1913; Dr Herbert Fox, Philadelphia chronic inflammatory tissue, diagnosis of tumor cannot be made from this section but there are areas suggesting giant cell tumor; Dr James Ewing, New York giant cell tumor; Dr J C Bloodgood, Baltimore giant cell tumor; Dr E A Codman, Boston giant cell tumor, necrotic; Dr J H Wright, Boston giant cell tumor; Dr S B Wolbach, Boston giant cell tumor; Dr F B Mallory, Boston chronic inflammation.

18 Roentgenograms made at the University Hospital in October and December, 1919, shown the author in 1921 by Dr Pancoast, revealed fracture of the surgical neck of the right humerus. No bone disease was noted in 1919, but reexamination in 1921, with knowledge of the patient's later condition, enabled one to appreciate a slight trabeculation in the region above the surgical neck, and in the second roentgenogram also a slightly greater atrophy and one which extends farther down the shaft than would be expected to follow disuse alone.

lower third of the arm. The thin cortex over the cyst was easily perforated by blunt instruments. Section of the cyst wall and a specimen of the contents of the cyst were sent to the laboratory. The cyst wall was only from 3 to 4 mm thick. It was fibrous only, with no trace of bone, where the cyst was entered. The contents resembled currant jelly, with small islets of yellowish

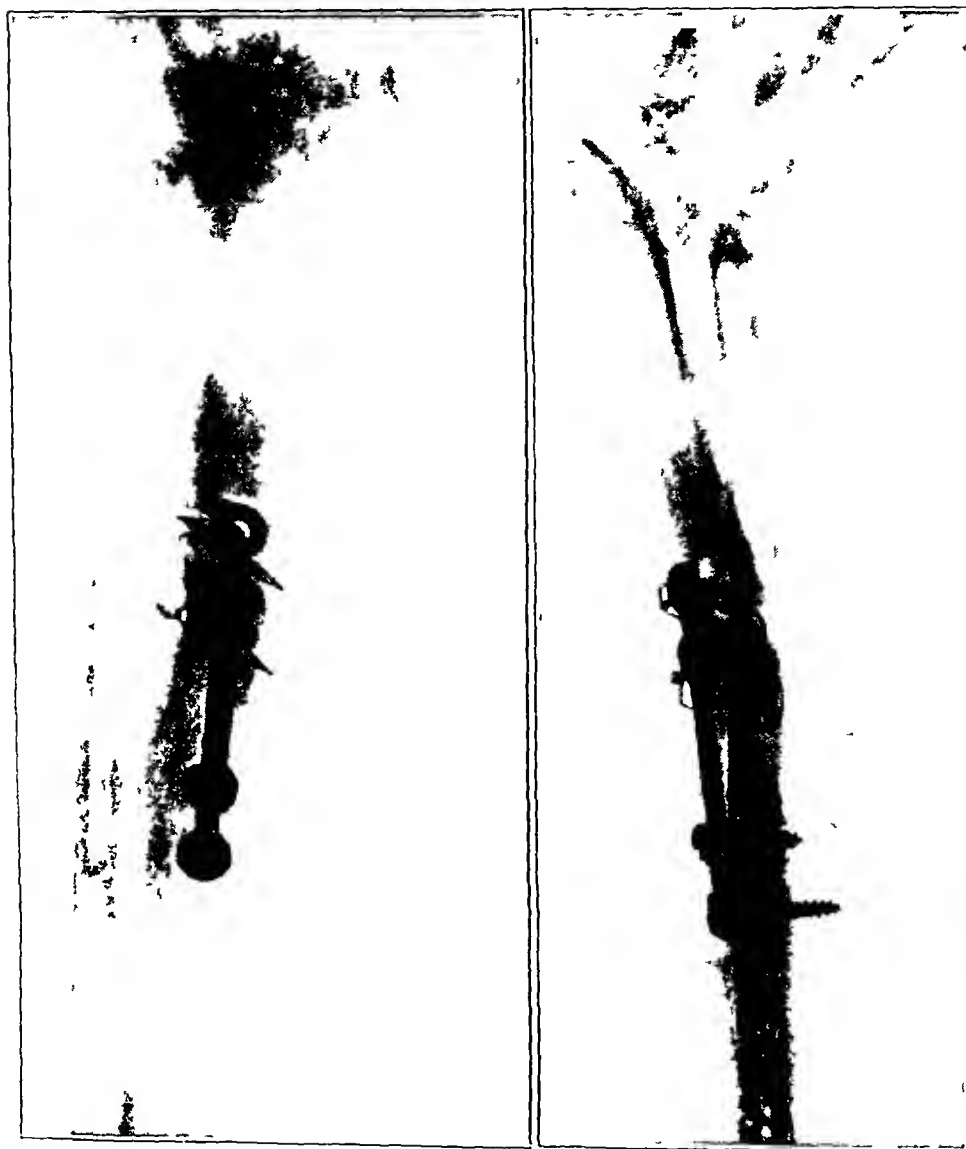


Fig 48 (Case 12) —Fracture of transplant through the most distal screw hole, nearly eight years after last operation

white fibrous tissue scattered throughout. Such very free (almost alarming) hemorrhage was encountered from the interior of the cyst that preparations were made to apply an Esmarch bandage around the shoulder but by rapidly evacuating all the soft tissue from the interior of the cyst and packing it with gauze temporarily, all bleeding stopped permanently.



An aperiosteal transplant (12 by 15 by 15 cm) was next cut by circular saw from the subcutaneous surface of the right tibia. In removing this by osteotome, the shaft of the tibia, which seemed unusually brittle, was accidentally fractured obliquely through the crest at the lower end of the transplant, and the transplant itself was fractured transversely near the center. One fragment of this transplant was placed within the bone cavity of the upper



Fig 49 (Case 12)—Appearance of arm, Feb 28, 1922, four weeks after removal of plate and screws shown in Figure 48. The dorsal surface of the lower end of the transplant was trimmed down at the same time to improve the contour of the wrist.

fragment of the humerus extending from the interior of the great tuberosity almost to the line of fracture. The second piece of the transplant was used to bridge the fracture of the humerus, being fixed below as an inlay in a slot cut in the anterior surface of the shaft of the humerus below the cyst, and its

upper end passing into the cavity of the upper fragment of the humerus. The section of bone removed from the humerus to admit the tibial inlay was also inserted into the cavity of the cyst (Fig 54). After closure of the incision in layers, a plaster-of-Paris dressing was applied to the entire upper extremity and chest, with the shoulder abducted about 45 degrees. The time consumed was one hour and forty minutes.

*Course*—Feb 14, 1921, the leg was dressed. The operative wound was healed. Two very small superficial abscesses in the calf of the leg had ruptured beneath the cast. Union in the fracture of the tibia was not very firm.

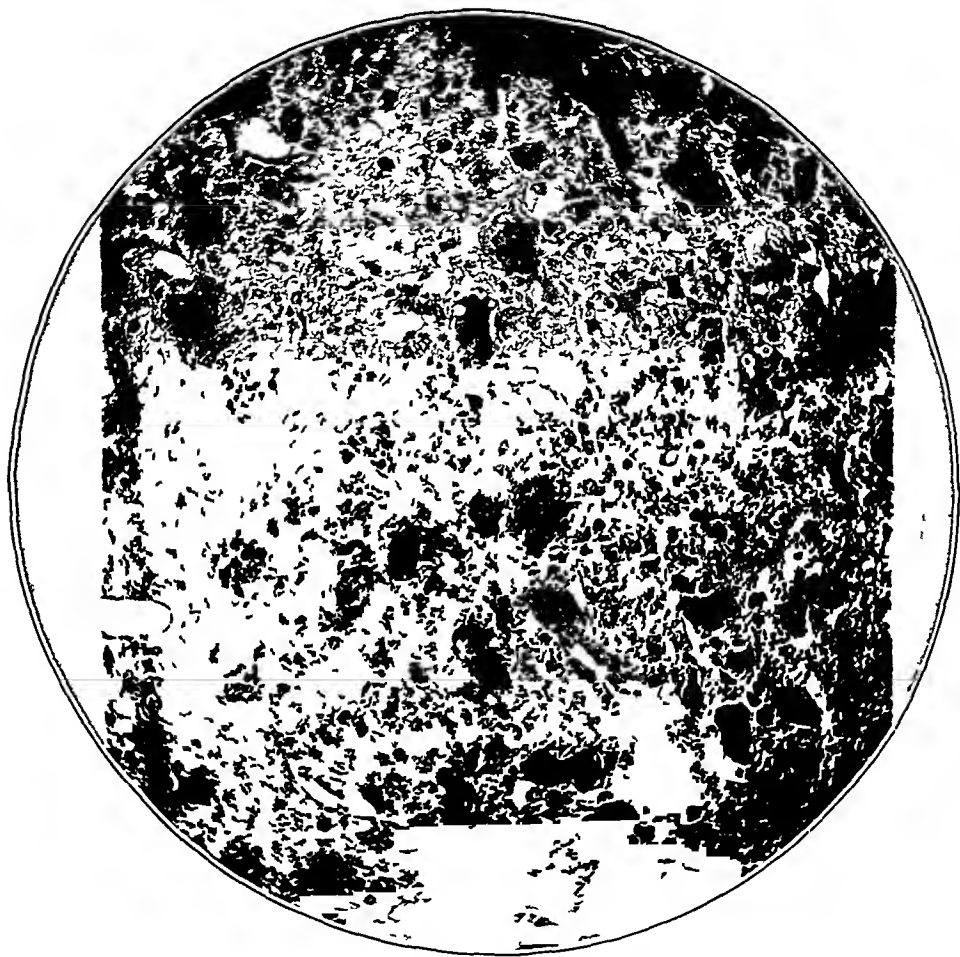


Fig 50 (Case 12)—Low power photomicrograph of tissue secured at first operation (1913) showing innumerable "giant cells" (benign) of the epulis type.

March 4, 1921, the leg had been dressed every few days. Today, six weeks after operation, the arm case was removed for the first time. The wound was healed firmly, and there was good union in the humerus. A roentgenogram was taken and a new plaster-of-Paris dressing was applied to the arm and chest. Union was firm also in the fracture of the tibia. The patient was discharged to return to the dispensary for further dressings (roentgenogram, March 4, 1921, Fig 55).

The gypsum dressing was permanently removed about twelve weeks after operation, and the patient then wore only a gypsum shoulder cap and carried his arm in a sling. Six months after operation he was able to resume light work.

Up to April, 1923, twenty-seven months after operation, there was no evidence of recurrence of the disease. The humerus was firmly united, roentgenograms revealed nearly normal regeneration of the bone, although the shaft of the humerus was still thickened and deformed (Fig 56), but the man had normal use of the arm, the only disability being from ankylosis of the

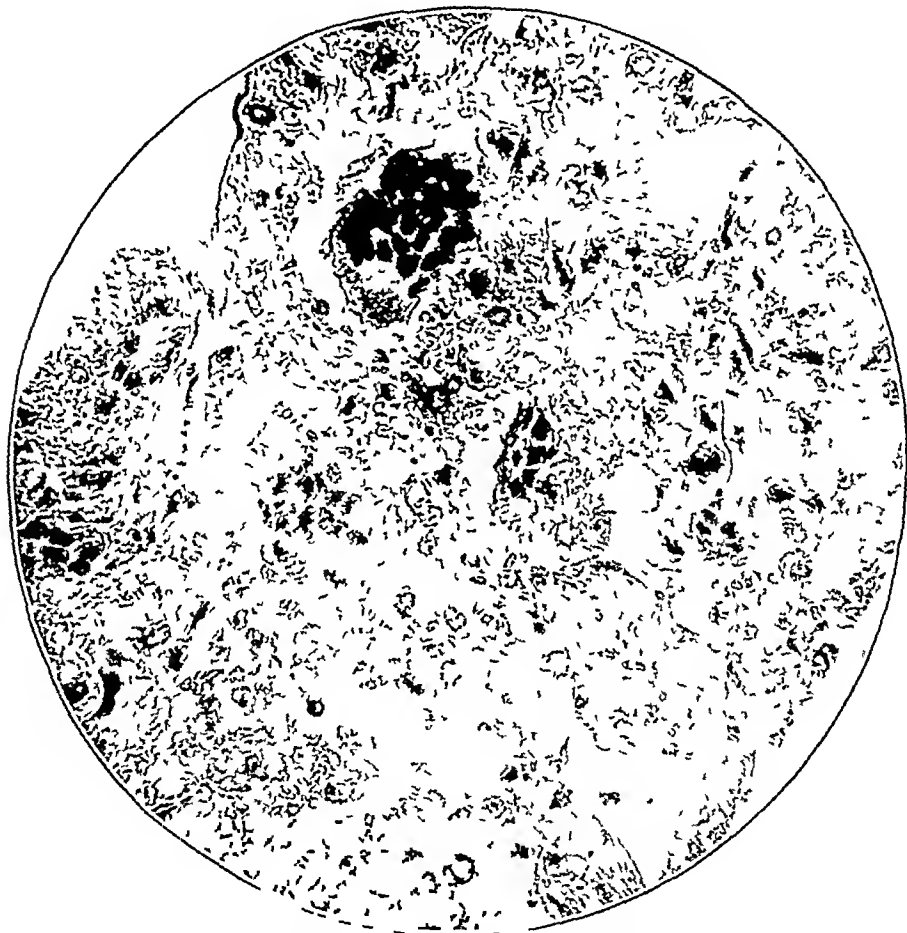


Fig 51 (Case 12) —High power photomicrograph of tissue secured at first operation in 1913, showing "giant cells" resembling megakaryocytes rather than foreign body giant cells (Prof W H F Addison, University of Pennsylvania)

shoulder, apparently bony, in abduction about 75 degrees, moderate external rotation and slight flexion.

*Pathologic Report* (Dr C Y White) —In general the tumor consisted of spindle cells arranged in irregular whorls, which cells had a large vesicular nucleus. The blood vessels were, in general, fully formed, but occasionally areas were encountered in which blood seemed to be in spaces. Elsewhere there were distinct hemorrhages, and in places this hemorrhage was wide-

spread between the cells. In these areas of hemorrhage there was much blood pigment in granules, some of it inside of phagocytes. In these areas were numerous giant cells of epulis type. These giant cells were less numerous in other areas.

In other sections of the tumor the cells were more crowded. Morphologically, they were of the spindle cell type, representing fibrous tissue cells of granulation tissue. In such areas the giant cells of the epulis type were far more numerous.

In one small area of one section were groups containing from four to five large cells in which the nuclei were centrally located, the cell walls were

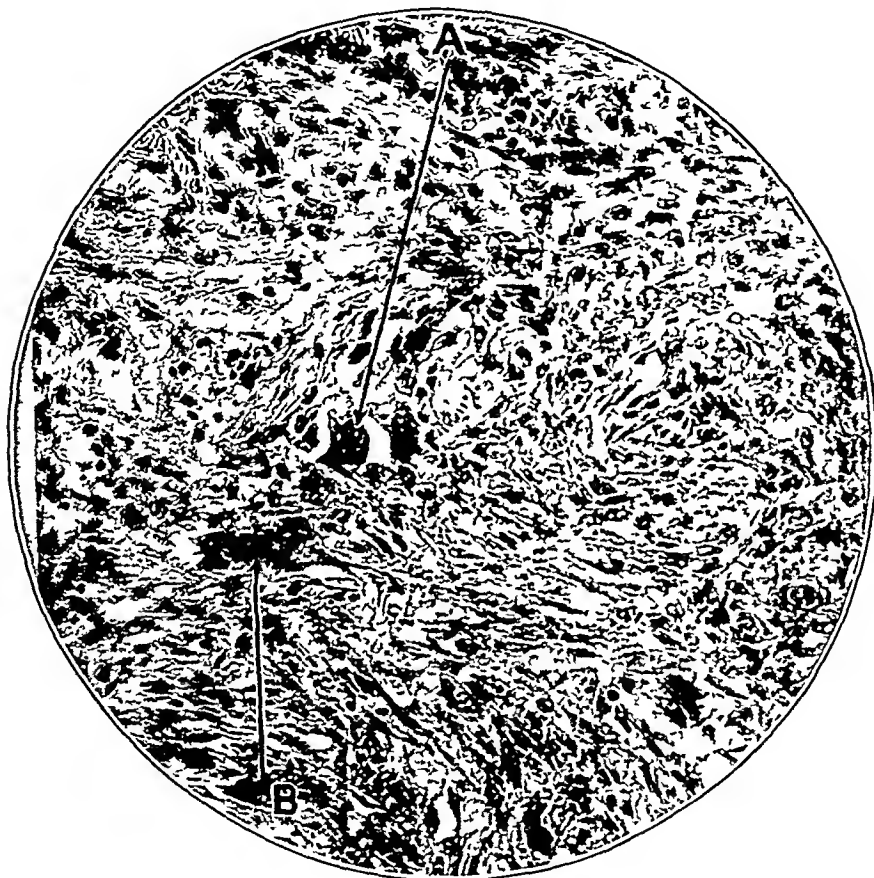


Fig 52 (Case 12) —High power photomicrograph of tissue from operation in 1914, showing appearances suggesting spindle cell sarcoma, with gigantic cells (true "tumor giant cells") *A* and *B*, gigantic cells

irregularly rounded, and the protoplasm did not stain, but showed a very faint reticulation between which was very fine, granular material resembling unstained fat. These cells looked like those described as fatty degenerated cells. Between these groups of fatty cells, the structure of the tumor was similar to that noted elsewhere in the sections, namely, spindle cell.

In sections showing bone, the tumor tissue had encroached on the dense bony trabeculae, infiltrating it in areas.

In some sections an occasional "gigantic" cell was seen.

**Diagnosis** This was giant cell sarcoma of bone marrow (giant cell tumor) with areas showing early spindle cell sarcoma (Fig 57)

These slides were also examined by the following pathologists, whose opinions are appended Dr Allen J Smith, Philadelphia "myeloid sarcoma malignant I have seen two similar cases in which metastases occurred",



Fig 53 (Case 13)—Cystic osteitis of the humerus

Dr John Speese, Philadelphia giant cell tumor, Dr Herbert Fox, Philadelphia spindle cell sarcoma, malignant, Dr J H Wright, Boston giant cell tumor, Dr S B Wolbach Boston giant cell tumor, Dr F B Mallory, Boston giant cell tumor, Dr J C Bloodgood, Baltimore giant cell tumor, and Dr James Ewing, New York xanthosarcoma

Dr Bloodgood's notes made in December, 1921, were

"It is an unusual picture. It suggests a picture described by Ewing as an endothelial myeloma. The most marked features are groups of palely staining cuboidal and pavement cells of the endothelial type in tubules and irregular cavities, often mixed with blood. Some cavities with blood without tumor cells. This portion is separated by a very cellular stroma, varying in thickness. Cells somewhat of the spindle type. When we look at the tissue surrounding the endothelial area we have a picture of a small spindle and round cell sarcoma. There are a few multinucleated cells. It seems to me we can exclude osteitis fibrosa, the giant cell tumor or inflammatory tissue. In the section there is no bone, no cartilage, no giant cells of the epulis type, nothing to suggest a typical multiple myeloma. The age of the patient, 37, is against osteitis fibrosa."



Fig 54 (Case 13)—Diagram showing method of insertion of transplants

Dr Bloodgood's notes of June 5, 1922, were

"There are not many giant cells, but the stroma is that of the benign giant cell tumor, or fibrohemangioma of the xanthoma type. I believe this is a benign lesion central in bone and should be placed with this group—benign giant cell tumor."

Dr Ewing's notes were

"Sections show xanthosarcoma, a cellular variety of the benign giant cell tumor. Some areas contain many large clear cells filled with lipoid granules. Others are very cellular with compact spindle cells, long and short nuclei slightly hyperchromatic. There are many blood spaces lined with a few giant cells of the epulis type. This tumor recurs locally. It belongs in the benign giant cell tumor class."

CASE 14—Cystic changes in an exostosis springing from the lesser trochanter of the femur in a patient with multiple cartilaginous exostoses. History—

Lieut G H M, a brunette man, came under my care in March, 1919, at the Walter Reed General Hospital, Washington, D C His previous history was negative In September, 1917, he was thrown from his horse, and during the three following months he had pain and soreness in the right groin and adductor

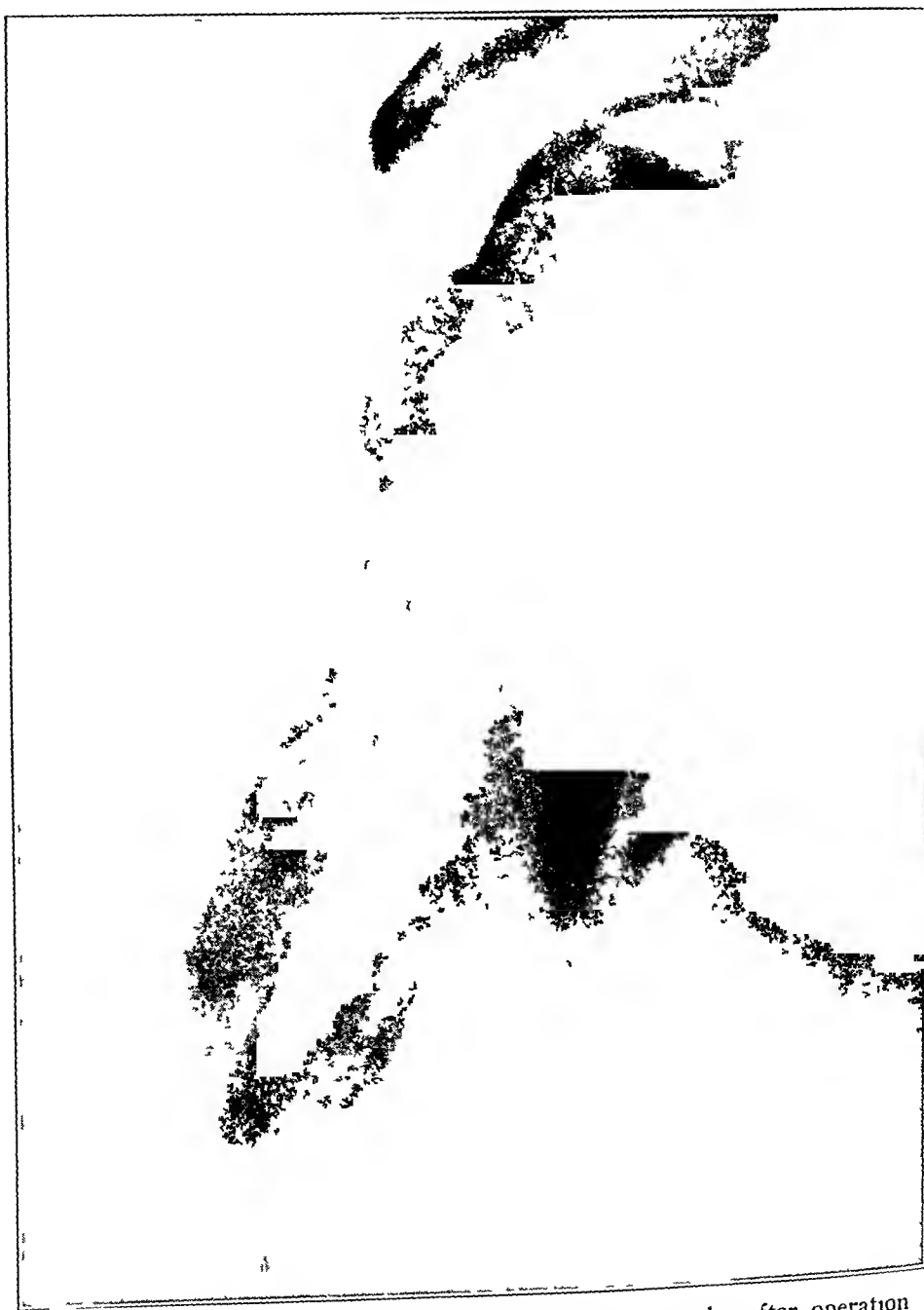


Fig 55 (Case 13)—Cystic osteitis of humerus, six weeks after operation

region of the right thigh Gradually, he became aware of the presence of a bony tumor in the latter region, which had steadily increased in size and interfered markedly with his walking He had a noticeable limp, complained of pain in the right sacro-iliac region, and at each step had to swing his right

lower leg far out from his body to keep the tumor from "interfering" In standing he kept the right hip abducted

*Roentgenographic Examination* (Major Selby) —This revealed exostoses over the entire body The largest, and that which was the cause of the symptoms, was the size of a small orange and sprang from the region of the lesser trochanter of the right femur (Fig 58), growing into the adductor region and



Fig 56 (Case 13) —Humerus, twenty-two months after operation

butting against the pelvis when attempts were made to adduct the hip Other exostoses were found in the following situations left lesser trochanter, lower third of both right and left tibias, middle of left femur and the transverse processes of the fifth lumbar vertebra and on the twelfth ribs There was hyperostosis of the shaft of the right fibula

The circumference of the right thigh was 3 cm greater than that of the left just below the perineum (59 versus 56 cm) There was normal motion



in the right hip except adduction, which was lost, and hyperextension and extreme flexion, which were painful. Though there were multiple cartilaginous exostoses, there were none of the deformities associated with the affection known as hereditary deforming chondrodysplasia. The patient's height was 173 cm, and the umbilicus was 99 cm from the floor.

It seemed to me that in this case the best plan would be to expose first the base of the exostosis at the lesser trochanter. This exposure is not very easy, but I believe then and I believe now that the safest exposure may be obtained by means of Lambotte's incision, which will be described presently. Then, after division of the narrow base of the exostosis, if the tumor proved

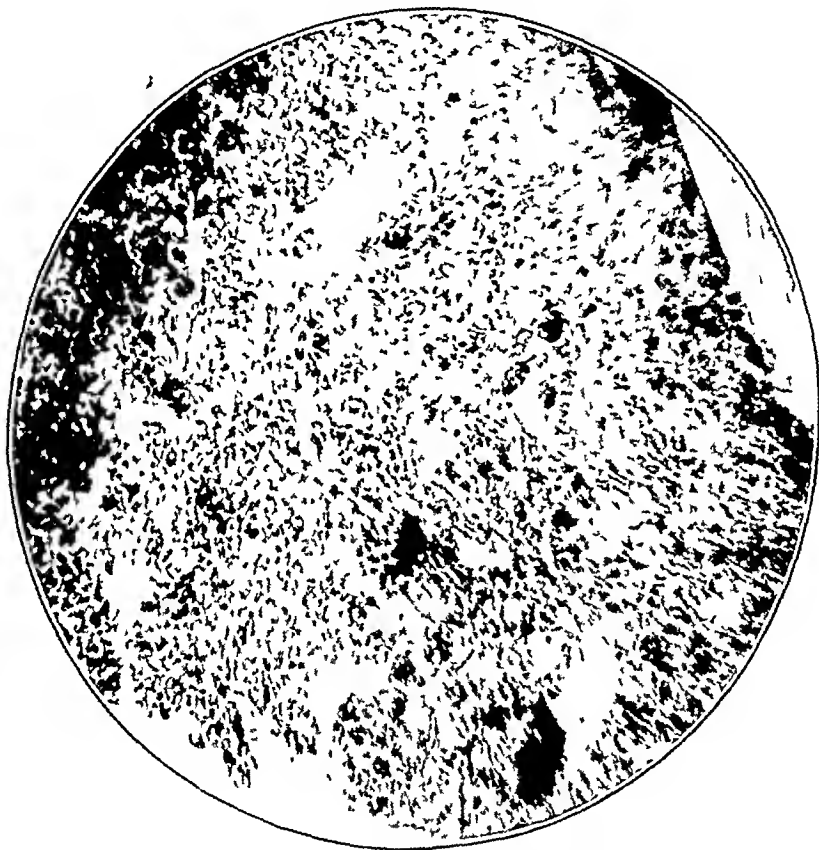


Fig 57 (Case 13) —High power photomicrograph of tissue secured at operation, showing sarcomatous appearance

adherent, or if, on account of its size, it could not be removed through the same wound, I determined to make a second incision in the adductor region, similar to that employed by Ludloff in cases of congenital dislocation of the hip, and complete the removal of the tumor by that route. Certainly, by the latter route the lesser trochanter cannot be easily exposed, even in the absence of an overlying tumor.

*Operation*—March 13, 1919, at the Walter Reed General Hospital, with the skilful assistance of Capt John T O'Ferrall, Lambotte's incision was made from the anterior superior spine of the ilium to the great trochanter, thence downward and forward for a distance of 12 or 15 cm. Then tensor fasciae

femoris and fascia lata were divided in the lines of the skin incision, and the flap drawn to the median side, the retractor protecting the great vessels. The usual approach, on the median side of the long tendon of the rectus femoris, proved so bloody that it was abandoned, and an approach on the lateral side of this muscle was adopted. Before baring the femur, it was necessary to divide the external circumflex vessels. Then the anterior intertrochanteric ridge was exposed, and on the median surface of this the pedicle of the tumor,



Fig 58 (Case 14) —Large exostosis, with cystic center, springing from right femur near the lesser trochanter

springing from the lesser trochanter, was identified and divided by chisel. It measured about 3 cm in its longitudinal diameter and nearly the same transversely. Attempts then were made to enucleate the tumor, but its wall was very easily broken through, and it had to be extracted piecemeal. Its interior was quite friable and soft, its surface was covered with cartilage. The wound was wiped out with hot mercuric chlorid and was closed in layers without drainage. It proved a difficult operation consuming more than two hours.

*Course*—Convalescence was uneventful, and when I returned from active service in the army, at the end of April, 1919, the patient was walking about with support. Under date of June 9, 1922, more than three years after operation, he wrote that the results had been "most encouraging and successful", and that he had about 75 per cent of the normal use of his right lower extremity. However, he still complained of some sacro-iliac and lumbar discomfort, perhaps from pressure of the exostosis in that situation.

*Laboratory Report*—The specimens removed at operation were examined by Capt M W Lyon, M C, of the Walter Reed General Hospital, who reported



Fig 59 (Case 15)—Cystic disease (angioma) of the tarsal scaphoid

there were no inflammatory cells and no neoplastic cells, there was normal hyaline cartilage, normal osseous material, white fibrous tissue, and a small amount of fatty marrow.

*CASE 15—Cystic disease (hemangioma) of the tarsal scaphoid History*—V D A, aged 35, an architect, was seen Sept 9 1916, referred to me by Dr Paul D Walter of Bethlehem, Pa, and Dr A G Sampson of Philadelphia. The patient had noticed in February or March, 1921, that his right foot and ankle felt as if they had been sprained, but he had no knowledge of any injury. He played tennis without disability during the summer of 1921, but in October of that year the pain in his foot began again. Roentgenograms made at

this time (not seen by me) are said to have shown some bone change, the character of which was not known. His foot troubled him throughout the ensuing winter, and, following an attack of acute tonsillitis in the early summer of 1922, the pain and disability became much worse. Roentgenograms made at this time by Dr Pfahler (Fig 59) showed definite cystic changes in the tarsal scaphoid. For the few months previous to visiting me in September, 1922, the disability had been steadily increasing, and for several weeks he had been entirely incapacitated, being barely able to hobble around with a cane. For the previous few days he had suffered acute pain all the time and had been unable to sleep. For many months he had been unable to wear golf trousers, because buckling them around his knee caused such severe pain in the foot.

*Examination*—Sept 9, 1922, the findings were negative except for the condition of the right foot. This showed a prominence on the median border of the scaphoid, so tender that it could scarcely be touched. The astragalus and internal cuneiform bones were not tender, and the rest of the foot appeared normal. Further roentgenograms showed the same condition as in Figure 59. Operation was advised and accepted.

*Operation*—Sept 16, 1922, at the Orthopaedic Hospital, under the diagnosis of "cystic disease" of the tarsal scaphoid, an incision, 10 cm long, was made on the median side of the tibialis anticus tendon, the incision being curved toward the sole at its distal extremity, so as to turn down a flap of the soft parts. The periosteum of the scaphoid bone was bulging outward on its median surface, the bone beneath felt cystic. The astragalus and internal cuneiform bones were normal. The periosteum of the scaphoid was incised longitudinally on its dorsal surface, exposing, in the interior of the bone, tissue which resembled currant jelly, and throughout which were very friable trabeculae of cancellous bone. From gross examination, it was thought to be a myeloma (giant cell sarcoma). A culture from the interior of the cyst gave no growth, and guinea-pig inoculation was negative for tuberculosis. The interior of the cyst was removed by curet, and specimens of the tissue sent to Dr E P Corson White, pathologist of the Orthopaedic Hospital, and to Dr C Y White at the Episcopal Hospital. These reports are appended. The proximal and median portions of the scaphoid were composed of normal dense cancellous bone. Distally, at the median border, the disease extended as far as the joint with the cuneiform, but the joint itself was not invaded. Thus, the cavity, about 2.5 by 2 cm, in the scaphoid was bounded by apparently normal bone proximally and laterally, and by bulging but intact periosteum medially and distally, the entire median portion of the scaphoid, except where it articulated with the astragalus, was cystic. This cavity was not cauterized in any way, but after thorough curettement was filled with Mosetig-Moorhof's iodoform bone wax. The periosteum was closed with continuous chromic catgut sutures, the deep fascia with interrupted chromic catgut sutures, the superficial fascia with interrupted chromic catgut sutures, and the skin with continuous chromic catgut sutures. Alcohol dressings were applied, and the foot placed in a gypsum splint in a position of slight varus and cavus.

*Course*—Oct 9, 1922, the skin sutures had been absorbed, and the wound was healed except at its middle where it was barely moist. Use of the gypsum splint was continued. The patient, who had been about on crutches since a few days after operation, had had no pain since the operation, even in damp weather, for more than a year before operation his foot had invariably pained him whenever the weather was damp.

Oct 25, 1922, a roentgenogram showed the wax in the bone cavity, the surrounding bone looked normal Use of the gypsum splint was discontinued

Nov 22, 1922, a little wax had exuded through the center of the incision, requiring change of dressings about once in ten days The patient had been wearing stout orthopedic shoes for the last week He still used a crutch on the street

Dec 7, 1922, the wound had healed since the last note The roentgen ray showed considerable bone regeneration and some of the wax still unabsorbed He walked without a cane

April, 1923, there were no symptoms

*Pathologic Report*—(Dr C Y White)—The section was composed of fibrous tissue with typical spindle cells areas showing atrophic bone and numerous various sized spaces filled with blood, and lined with endothelial cells Also there were large areas showing blood pigment, and a number of giant cells

Diagnosis Hemangioma cavernosum of bone (Fig 60)

Dr E P Corson White reported The tumor mass invading the bone was made up largely of flat endothelial cells with flat nuclei, which tended to form cystlike cavities often filled with blood The cavities were backed by connective tissue stroma Mitotic figures were present but not numerous In places the cells were collected in more or less concentrated masses, between which fibroblasts had grown These areas were at times suggestive of malignancy, but probably were not malignant

Diagnosis Hemangioma

Dr Allen J Smith reported The specimen represents ossifying endosteitis, or, if a tumor, telangiectatic osteosarcoma, relatively benign

#### DESCRIPTIONS OF ROENTGENOGRAMS BY DR BROMER

Figure 1 illustrates an area of decreased density, apparently cystic in nature, in the lower third of the tibia along its anterior border, with a definite line (which is evidently proliferating periosteum) outlining the anterior border The remainder of the shaft shows typical bone changes of syphilis From the roentgenographic appearance, it is impossible to determine definitely whether this rarefied area has a bony shell as a covering or whether the shadow apparently overlying it is caused by one of the edges of a troughlike erosion caused by the syphilitic process

Figure 2 presents a cystic condition that is very unusual, involving as it does the diaphyses and the epiphyses of the fibula and the tibia and all bones of the tarsus There is extreme atrophy of the shafts of the tibia and the fibula, quite frequently seen in congenital syphilis The involvement of the long bones of all the limbs would tend to indicate that it is a systemic infection The expansion of the thinned out cortex is abrupt as in giant cell tumors, but in the latter all neighboring bones are never simultaneously involved as are the tarsal bones in this case

Figure 3, from Case 1, shows the area of osteolysis plainly starting from the medullary cavity and encroaching on the surrounding

cortex, assuming an elliptic shape. There is definite cortical thickening and deposition of new bone. The periosteum shows proliferation, but nowhere is the latter perpendicular to the shaft, the newly formed bone being deposited longitudinally. Knowing nothing of the history of this case, I believe it could be fairly assumed to be an infectious process. The differentiation between syphilis, chronic osteomyelitis and tuberculosis is, however, impossible. The fact that cortical thickening and regeneration are marked would tend to rule out tuberculosis.

Figures 4 and 5 illustrate a cystic condition of bone with trabeculation and the appearance of a multilocular cystic area of rarefaction. However, in the anteroposterior view, there is definite periosteal proliferation laid down longitudinally, which would put it in the class of the infections. There is little tendency to overproduction of bone, and there is the cortical thickening as seen in Case 1. This would narrow the diagnosis to a consideration of tuberculosis alone.

Figure 6 shows a rarefied area, a cystic condition, in the upper extremity of the ulna. It involves both the diaphyseal end and the epiphysis of the olecranon. There is no periosteal reaction. Trabeculae are not clearly defined. There is nothing to indicate tuberculosis, although this was definitely established after operation. It is almost identical to a case of fibrocystic osteomyelitis reported by Barrie,<sup>2</sup> who states that tuberculosis rarely causes fibrocystic changes in bone. In our experience it would seem to be a more frequent cause. He states that these fibrocystic lesions do not increase in size, but that it is impossible to differentiate them from chronic sterile bone abscesses which also do not increase in size.

Bloodgood<sup>8</sup> calls attention to the fact that in a few cases of tuberculous osteomyelitis localized in the shaft of long pipe bones, or in the epiphysis (for example, the lower end of the radius), a central rarefied shadow may be present surrounded by a bony shell with no ossifying periostitis. This case would seem to be an example of such a condition.

In Figure 7 a cystic area, with slight trabeculation, thinning of the cortex and slight expansion in the upper extremity of the humerus, is seen, differing from the picture of chronic cystic osteitis in that the unexpanded portion of the cortex is not involved in the pathologic process. The pathologic fracture can plainly be seen. There is no periosteal reaction, and on this account the infections, syphilis, chronic osteomyelitis and tuberculosis, can be ruled out. The exception to this rule must be borne in mind, however. The cortex does not show the abrupt expansion so often seen in giant cell tumors, and for this reason the latter could be excluded. This narrows the diagnosis to a so-called true bone cyst.

Figures 11, 12, 13, 20 and 21 illustrate cases of multiple fibrocystic osteitis which should not be difficult to diagnose. In these two cases

the characteristic replacement of normal bone detail by irregular strands of trabeculae is seen, enclosing multiple cysts which vary in size and shape. The bony cortex is expanded and thinned. The characteristic deformities, usually bowing of the long bones, with the convexity either inward or outward, are present.

In this connection the observation of Strom<sup>19</sup> should be noted. He cites a case in which the diagnosis of osteitis fibrosa was made only with the greatest difficulty. The lesion was situated in the upper extremity of the humerus, and was characterized by quite extensive deformity of that portion of the bone. The outline of the remainder of the bone was quite normal, but the structure was abnormal, suggesting a cavity formation. The cortical portion in the deformed area was thinned and pressed outward. Close study of the remainder of the shaft revealed the same thinning of the cortex with increase in the marrow cavity, although the outlines of the shaft and the diameter agreed with those of its fellow of the opposite side. He emphasizes the fact that the decisive feature in osteitis fibrosa is not found in the deformed part alone, but in the involvement in the morbid process of the greater portion of the nondeformed part of the bone. This is necessary to rule out the possibility of local neoplastic formation.

The large cyst of the first metatarsal in Case 7 (Fig 11), involving the entire bone, is merely the picture of a cyst with no distinguishing characteristics. No trabeculae enclosing multiple cysts can be seen. If the patient had not shown the other lesions typical of chronic cystic osteitis, there would be no means whatever of differentiating between it and a so-called true bone cyst.

In Figure 29 the humerus, from its upper diaphyseal extremity downward, for the space of almost half of its length, shows a large cystic area. The cortex is thinned and expanded so that the total diameter is approximately twice that of the normal shaft. Trabeculae are seen. A pathologic fracture is present.

The first condition coming to mind is fibrocystic osteitis, although the so-called true bone cysts show trabeculation. I do not believe a diagnosis of either can be made from the roentgenogram alone. In the unaffected portion of the shaft, the extension of the pathologic process does not show, as it did in the case of Strom<sup>19</sup>. As previously remarked, he considers this finding quite essential in the diagnosis of fibrocystic osteitis.

The pathologist reported "cystic osteitis with giant cells." If he considered it a giant cell sarcoma or myeloma, it certainly serves to

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19 Strom, S. Roentgen-Ray Differential Diagnosis Between Osteitis Fibrosa, Solitary Bone Cyst and Tumors, *Acta chir Scandinavica* 53:21 1920

show that the differential diagnosis of these three conditions, true bone cyst, myeloma and fibrocystic osteitis, is impossible by means of the roentgen ray alone

In Figures 33 to 35 the globular shadow arising from the right side of the fourth and fifth lumbar vertebrae does not show definite characteristics of any new growth. Figure 35 shows slight reticulation. All show a limited outline, as though no invasion was present. A giant cell tumor might be considered.

Figure 39 illustrates Case 11 in which the clinical and roentgen-ray diagnosis was giant cell sarcoma or myeloma. The pathologic report was hardly satisfactory, inasmuch as the type of tumor was not stated. It does not resemble a giant cell growth, inasmuch as there is very slight, if any, expansion of the bony shell, although the dark lines forming trabeculations are present. Granted that expansion is present, it certainly is not the abrupt expansion noticed so frequently in the proved giant cell tumors. If compared with the chondroma carefully studied and reported by Bloodgood,<sup>20</sup> the roentgenographic appearance would seem to be identical.

In Figures 40 and 43 the lesion resembles very closely the typical textbook picture and description of a giant cell sarcoma or a myeloma. It is located at one end of a long bone, viz, the lower end of the radius, one of the bones most frequently affected. The cortex is thinned, the expansion beginning abruptly. The growth is equal in all directions and is reticulated. This, to my mind, is a most typical giant cell sarcoma.

In Figure 53 the lesion shows none of the characteristics of a malignant growth. It rather resembles a chronic cystic osteitis or a myeloma (giant cell sarcoma). The cortex is thinned and expanded. Trabeculae are present. There are shadows of rarefaction in the unexpanded portion of the bone, suggesting chronic cystic osteitis, pointed out by Strom<sup>19</sup> as a distinguishing feature of this condition. The age of the patient would tend, of course, to rule this out. The appearance resembles somewhat, too, a giant cell tumor, but the expansion of the cortex is not quite so abrupt as is often seen in these lesions.

Baetjer<sup>10</sup> gives this description of a typical spindle cell sarcoma of bone: "While spindle cell sarcoma is malignant, it does not seem to be as invasive when seen upon the roentgen-ray plate. It destroys equally in all directions, is generally medullary in origin, does not expand the cortex, but destroys it. The growth, however, does not show the same degree of invasion and may be taken for osteomyelitis. It gives the appearance of being slightly limited in its extension through the medullary canal."

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<sup>20</sup> Bloodgood I C Footnote 8 Page 180 Figure 15



It can easily be seen that this case presents nothing like the description of Baetjer. Nor can I find in the literature the description of a spindle cell sarcoma presenting a like cystic appearance. The present condition of the patient, more than two years after the operation with no recurrence, would tend to confirm the clinical and roentgen-ray diagnosis rather than the pathologic.

From Figure 58 the diagnosis was comparatively easy, especially since other exostoses were found on examination of the long bones. According to Bloodgood,<sup>8</sup> the exostosis rests upon a foundation of normal bone, while the exosteal growth is composed chiefly of cancellous bone. It may show an outer condensed zone of bone, and there is usually little periosteal bone formation about its base. The roentgen ray reveals little evidence of the cystic condition found at operation.

In Figure 59 the inner half of the tarsal scaphoid shows a cystic formation with trabeculae. There is no invasion of the soft parts. The remainder of the bone seems to be unaffected. No other bones of the tarsus or the foot are involved. This seems to be a case in which a definite roentgenologic diagnosis is impossible. It might be a solitary bone cyst, or possibly a giant cell sarcoma. The latter usually show much more abrupt expansion of the cortex. The lack of invasion would seem to rule out a malignant condition. If the correct diagnosis is cavernous hemangioma or endothelioma, it is the first encountered by us, and serves again to emphasize the impossibility of exact roentgen-ray diagnosis of these lesions.

# ARTIFICIAL NERVE BRANCHES FOR INNERVATION OF PARALYZED MUSCLES \*

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When a nerve trunk is injured at a level at which important muscular branches are given off, it follows almost invariably that the muscles supplied by these branches are permanently paralyzed, since no path for the conduction of neuraxes from the nerve trunk to the muscle is available. To find a means of forming nerve branches artificially, so that such a path may be furnished for the neurotization of muscles, has been the object of this research. Experimentally, a method has been found whereby a nerve trunk may be made to grow nerve branches at any level in its course and to supply any given muscle which it may formerly have supplied. A muscle normally in the domain of one nerve may be reinnervated by an artificial nerve branch from another nerve without impairing materially the function of the latter.

Artificial nerve branches may be made by using a free autogenous nerve transplant, preferably a small cutaneous nerve, the central end of which is sutured into the nerve trunk and the distal end directly into the muscle to be innervated. By this means, for example, the flexor carpi ulnaris muscle may be neurotized, when its muscular branches have been destroyed, by forming an artificial branch from the ulnar or from the median nerve. Or, if the musculocutaneous nerve is destroyed high up, so that its central end cannot be implanted directly into the biceps, an artificial muscular branch may be made from either the median or the ulnar nerve and implanted into the biceps. The combinations which may be employed are thus rather numerous and are further increased by the fact that more than one artificial branch may be made from a nerve.

The basis of this method lies in principles which are established both experimentally and clinically. First, downgrowth of neuraxes from the central end of a severed nerve trunk can be carried to the distal end by means of a free nerve transplant. Second, if the whole central end of a severed nerve is implanted into a paralyzed muscle, neurotization of the muscle takes place. In the formation of an artificial nerve branch, a small free nerve transplant is sutured to part

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\*From the Department of Neurology, Laboratory of Experimental Neurology, Columbia University.

\*Read before the combined meeting of the New York Neurological Society and the Neurological Section of the New York Academy of Medicine, Nov 14, 1922.

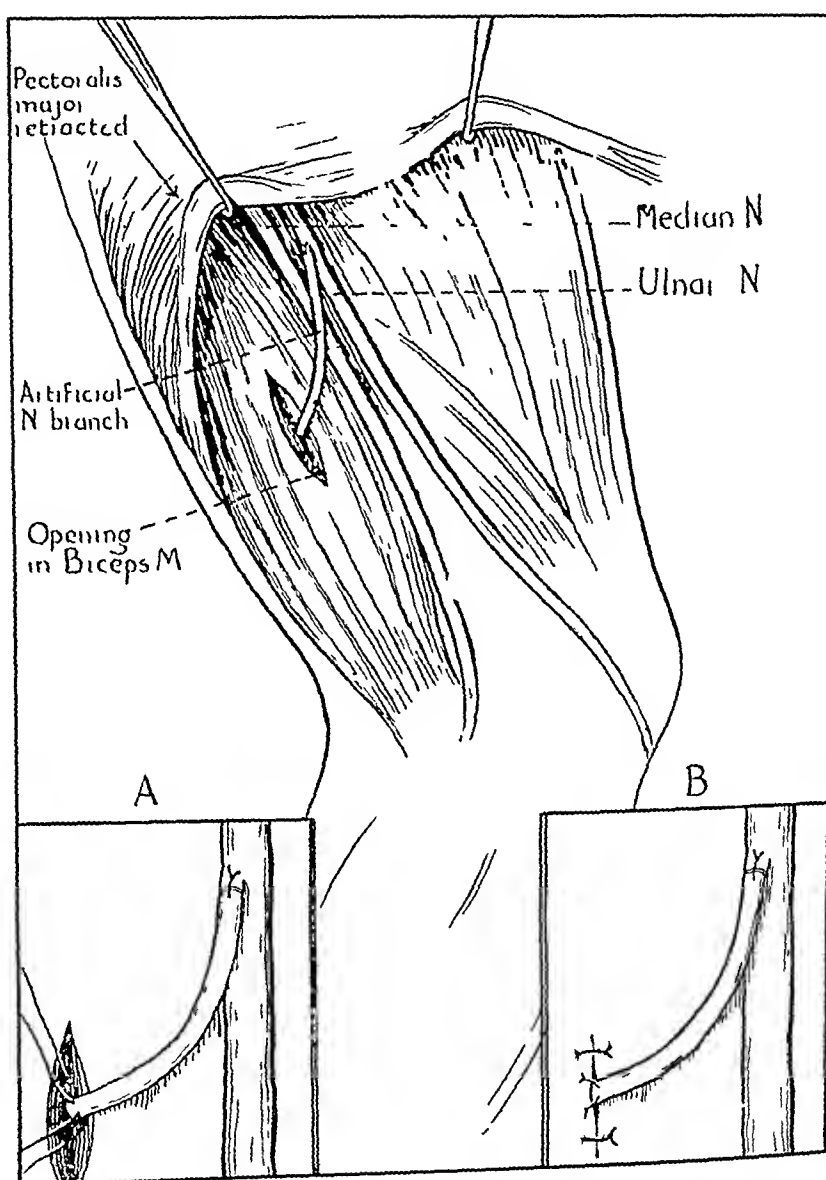


Fig 1—Schematic drawing illustrating the method used to form artificial nerve branches. An incision is made in the parent nerve trunk in order to cut sufficient funiculi to cover the cross area of the free nerve segment to be used as a conduction path from nerve to muscle. One through-and-through fine waxed silk suture is passed through the central end to form the central union, and two similar sutures are passed through the epineurium, 2 mm from the distal end of the nerve segment. The latter sutures are passed into a slit in the muscle as mattress sutures, as shown in A. The opening in the muscle is then closed with catgut, and two additional epineural sutures are placed to prevent angulation of the nerve (B).

of a nerve trunk and utilized to carry the downgrowing neuraxes directly to the muscle. The free end of the transplant is implanted into the paralyzed muscle just as is the severed end of a whole nerve trunk, and neurotization follows in like manner.

An incision into the nerve trunk is made as if a partial nerve crossing were to be performed, only sufficient funiculi being cut to cover the thickness of the free nerve segment to be used as the artificial branch. A sort of flap is thus formed, but it is raised from the parent trunk only enough to permit accurate end-to-end approximation of the severed funiculi and the free nerve segment.

When neuraxes are cut, we know that in the process of regeneration the central end of a single neuraxis may form a number of neuraxes

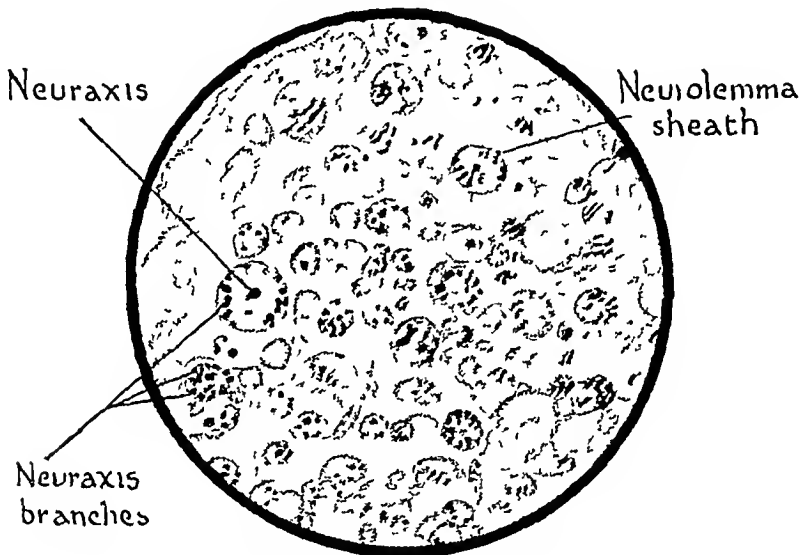


Fig 2—Cross-section through a nerve transplant, showing downgrowth of neuraxes and numerous neuraxis branches within a single neurolemma sheath. Ranson pyridin silver stain, paraffin section,  $\times 430$ .

As many as ten or twenty may be seen in cross-sections within the same neurolemma sheath (Fig 2). By leaving the nerve flap and line of suture in situ, some of the newly formed regenerating neuraxes which do not grow into the artificial nerve branch may find their way down their old sheaths and regenerate within the distal part of the nerve trunk. While it has not been possible to demonstrate that these neuraxes do find their way into the old sheaths, the possibility of their further downgrowth in them is at least not precluded. Thus, the loss of neuraxes to the nerve trunk may be diminished if the artificial nerve branch is brought to the nerve trunk and if the flap is raised only sufficiently to permit suture.

The distal end of the artificial nerve branch is implanted into the muscle to be neurotized as near as possible to the motor point of the muscle, that is as near as possible to the point where the muscular branch entered the muscle. This point of implantation is to be preferred, since it is the physiologic point of entrance of the nerve. However, it is not essential, since neurotization of the muscle may take place irrespective of this. In selecting the point for implantation, sufficient allowance should be made to prevent tension on the nerve during contraction of the muscle or movements of the extremity.

To implant the distal segment, a slit is made in the muscle in the direction of the muscle fibers and hemostasis obtained by placing a small bit of moist, warm cotton in the opening thus made, and waiting a

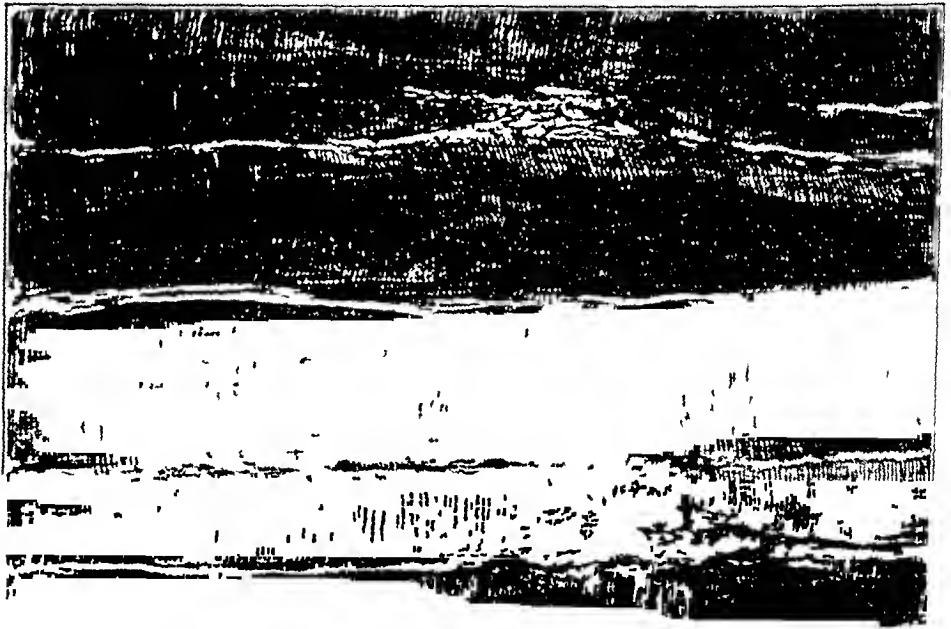


Fig 3—Longitudinal section through paralyzed biceps muscle innervated by an artificial nerve branch from the ulnar nerve, 139 days after section of the musculocutaneous nerve. Normal striations and normal size of muscle fasciculi indicate regeneration. Ranson pyridin silver stain, paraffin section,  $\times 430$ .

moment. Two fine waxed silk sutures are passed through the epineurium of the nerve segment at opposite points, about 2 mm from the distal end. The nerve end is then buried in the muscle by passing the epineural sutures into the muscle as mattress sutures (Fig 1). The opening in the muscle is then closed with catgut, and two additional epineural sutures are passed to hold the nerve in place and prevent kinking at the point of implantation.

It is conceivable that, by the time the neuraxes have grown from the nerve trunk through the nerve branch to the muscle, the distal implanted

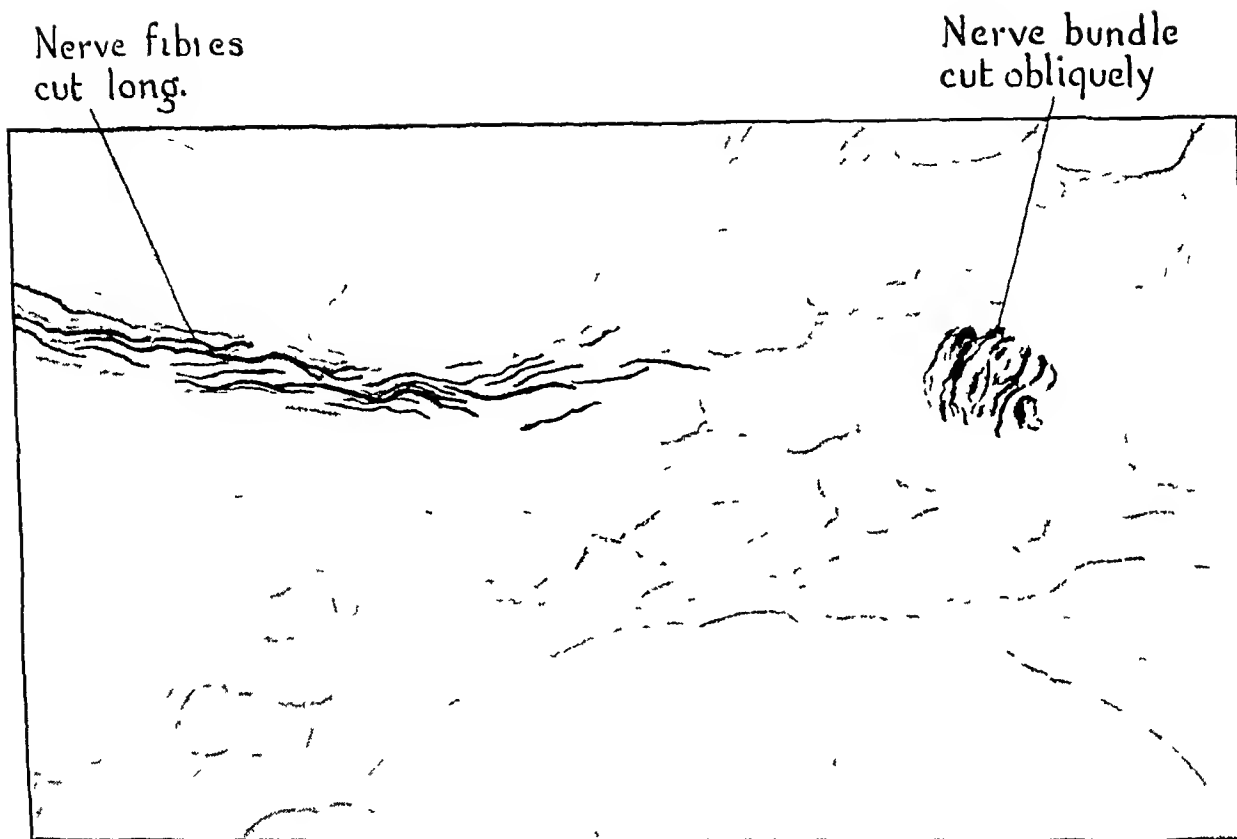


Fig 4—Cross-section through paralyzed biceps muscle innervated by an artificial nerve branch from the ulnar nerve, 239 days after formation of an artificial nerve branch. A small nerve bundle is cut obliquely, and nerve fibers are seen passing between the muscle fasciculi. Appearance of muscle, normal. Ranson pyridin silver stain, paraffin section,  $\times 430$ .



end of the nerve branch may be closed off or blocked by connective tissue, and neurotization prevented. While this is theoretically possible, it has not occurred in our experiments. However, should this contingency arise, the nerve branch may be cut at the point of implantation and reimplanted into the muscle at a higher level. The artificial nerve branch at this time would contain neuraxes. If it is then cut at the point of implantation, neuraxes are ready to grow at once into the muscle at the site of the fresh implantation without waiting for down-growth from the main nerve trunk to take place. The time interval for ingrowth into the muscle is thus diminished, and neuraxes may stream into the muscle before scar tissue can block them.

In selecting the point on the nerve trunk for suture of the artificial nerve branch, it would perhaps be preferable, on general physiologic grounds, to choose a level near which muscular branches formerly came off for the supply of the muscles to be innervated, though any level may be used and neurotization obtained. If an artificial muscular branch is to be made for a muscle foreign to a given nerve, a point should be selected, so far as possible, some distance from the other branches of the main nerve, so as to allow for rearrangement of the nerve fibers within the nerve trunk. If this precaution is followed, there will be less likelihood of serious interference in the peripheral distribution of the nerve used. Obviously, it is possible that the function of the main trunk may be interfered with, and a definite paralysis may result, even if due regard is had for the funicular anatomy as it is now known. But there are only a few nerves in which the funicular arrangement is definitely determined a great distance from the point at which the muscular branches are given off, for example, the funiculus to the pronator radii teres and flexor carpi radialis which can be traced centrally in the median nerve as far as the union of the outer and inner heads. Yet in most nerves, there is a surplus of nerve fibers, and numerous internal nerve plexuses for rearrangement of the fibers, so that the possibility of a definite paralysis may be diminished though it should always be borne in mind. The possibility of an additional partial paralysis is a point against the method which I wish to stress, and it is also important to point out that with due regard for the neural anatomy and delicacy in technic such paralyses may be reduced to a minimum.

In all, five dogs were used in our experiments. The musculocutaneous nerve was cut immediately after its formation. The central end was then tied with silk to prevent outgrowth of neuraxes, and, as a further precaution, the central end was implanted into the pectoralis major muscle. The site of the implantation was doubly closed by suturing the muscle over the opening in two layers. At the termination of the experiment, the musculocutaneous was stimulated centrally, and in no instance was there any response in the biceps or even in the



pectoralis major, showing that regeneration and ingrowth from the musculocutaneous to the biceps had not taken place, probably owing to the fact that the end of the nerve was tied off

In some instances in previous experiments, it was found that the biceps muscle may receive a branch from the median nerve, this apparent anomaly is to be expected if the fact is realized that the musculocutaneous in its development at one time was but a branch of the median and that the median may take over a part or the whole of the supply of the musculocutaneous. To prevent any such branch from supplying the biceps, a careful dissection was made along the biceps and the median nerve, and the median nerve was isolated and stimulated throughout to determine the presence of any such branch. In one instance, this branch was found, and it was treated in the same manner as the musculocutaneous, that is, the branch was cut, tied and buried elsewhere.

#### PROTOCOLS

EXPERIMENT 1 (Nov 2, 1921) —A medium sized black French poodle was used. The nerves on the inner side of the arm above the elbow were exposed in the usual manner. When the median nerve was traced, there seemed to be two branches, one on either side of the brachial artery. These were traced beneath the artery, where they united at the biceps tendon and passed in the direction taken by the median nerve. The dissection of the biceps was made to make sure that no branches entered from either the median, ulnar or the musculospiral nerve.

The ulnar nerve was isolated in the middle third of the arm, and an adjacent skin branch, 3 cm long, was freed and cut after a waxed silk suture had been passed at either end. The method of treatment of the musculocutaneous and the technic of the suture were described above.

*Comment* —It was extremely difficult to suture the central end of the free nerve segment because the ulnar was extremely small, however, a partial nerve crossing was done satisfactorily. The dog died after twenty-four days. The biceps presented the typical appearance of denervated muscle. No electrical tests were performed because the dog was found dead.

EXPERIMENT 2 (Nov 3, 1921) —A brown bulldog, with white on its neck, was used. The nerves on the inner side of the arm were exposed in the usual manner. Dissection was made to make sure that no abnormal branches entered the biceps. Treatment of the musculocutaneous and the technic of suture were those previously employed. The point of implantation was 1 cm below the point of entrance of the musculocutaneous into the biceps. When the musculocutaneous nerve was incised, a larger vessel was cut, and considerable bleeding was encountered. When the sutures were inserted at the point of implantation, a small vein was transfixed. Unfortunately this caused much bleeding at the point of implantation. The dog was killed, March 23, 1922, 139 days after the beginning of the experiment.

A dissection was made of the operative region, the biceps was exposed, and the artificial nerve branch readily seen from its origin on the radial border of the ulnar nerve to the site of implantation. The musculocutaneous was identified centrally and traced to the point where it was embedded in the pectoralis major

The musculocutaneous nerve was stimulated by a faradic current of various intensities. No response was obtained in the biceps or in any other adjacent muscle. The median nerve was then isolated and stimulated. No contraction was obtained in the biceps, thus ruling out the possibility of the presence of any abnormal branch to the biceps. The ulnar nerve was isolated centrad to the origin of the artificial nerve branch. On stimulation, the biceps contracted forcibly, as well as the ulnar musculature. The nerve was then stimulated below the origin of the artificial nerve branch, and contraction was obtained in the normal peripheral distribution of the ulnar nerve. Stimulation of the artificial branch resulted in a quick response in the biceps. The biceps muscle appeared normal.

Specimens were removed and placed in ammoniated alcohol.

EXPERIMENT 3 (Nov. 5, 1921).—A large white bulldog was used. The technic was the same as that employed in the former experiments throughout. A 3 cm. segment was cut, and the suture of the ulnar nerve was made along the radial border of the latter. The site of implantation into the biceps was on the superficial surface, just below the point at which the musculocutaneous entered it.

*Comment*.—Both the implantation and the suture were satisfactorily done. There was no bleeding, and good results were expected. The dog was killed, July 20, 1922, 256 days after the beginning of the experiment.

A clean dissection was made of the operative field, exposing the nerves as they arose from the brachial plexus. The musculocutaneous, median and the musculospiral nerves were isolated and stimulated separately. Contraction occurred in the normal distribution of the median and musculospiral, but no contraction occurred in the biceps on stimulation of the musculocutaneous. No response was obtained in either the biceps or the pectoralis major, into which it had been implanted after being tied off.

The ulnar nerve was then stimulated centrad to the origin of the artificial nerve branch. Contraction of the biceps was rapid and complete, causing rapid and quick flexion of the forearm. Stimulation of the branch itself also caused contraction to the biceps. No contraction was noted in the peripheral distribution of the ulnar on stimulation of the artificial nerve branch. Stimulation of the ulnar nerve above and below the artificial nerve branch resulted in contraction in the peripheral distribution.

The biceps muscle appeared normal in size and reddish. There were no fibrillations, and no yellowish color, such as is seen in denervated muscle.

The specimen was removed and placed in ammoniated alcohol.

EXPERIMENT 4 (Nov. 23, 1921).—A large black woolly haired dog was used. The same technic was employed as in the foregoing experiments. The dog was extremely fat, and considerable difficulty was encountered throughout the operation. There was considerable bleeding, and the central union of the nerve segment was not very good.

The dog died after thirty-one days. The muscles presented the typical appearance of denervated muscle. The point of union of the nerve segment with the ulnar and biceps was readily seen, and there was very little scar tissue. The dog died during the night, no electrical stimulations were done.

EXPERIMENT 5 (Nov. 30, 1921).—A large tan and white hound was used. The technic throughout was identical with that employed in previous experiments. There was very little bleeding, and the suture point was satisfactorily determined. The implantation into the biceps was made on the under surface of

the biceps. The whole operation was satisfactory, and good results were expected. The animal was killed, July 27, 1922, 239 days after the beginning of the experiment.

The operative field was exposed in the usual manner, and the nerves isolated as they arose from the brachial plexus. Stimulation of the median, musculocutaneous and musculospiral caused no contraction of the biceps. The musculocutaneous had been implanted into the pectoralis major after it had been tied off, and no contraction took place in the pectoralis major on stimulation of the musculocutaneous.

The artificial nerve branch from the ulnar to the biceps was readily seen. Stimulation of the ulnar nerve central to this branch caused contraction of the biceps. Stimulation of the artificial nerve branch caused contraction of the biceps. Contraction in each instance was forcible and caused flexion of the forearm. Stimulation of the ulnar nerve above and below the artificial nerve branch caused contraction in the peripheral distribution of the ulnar nerve. The biceps muscle appeared normal in size and of the normal reddish color. No fibrillations were seen. Specimens were removed and placed in ammoniated alcohol.

#### CONCLUSIONS

- 1 When muscular branches are destroyed and nerve suture is impossible, paralyzed muscle may be innervated by the formation of an artificial nerve branch.

- 2 When a free nerve transplant is sutured to the nerve trunk and the distal end implanted directly into the muscle, the free nerve transplant serves as a conduction path from the nerve trunk to the muscle.

- 3 An artificial nerve branch may be made for a muscle from a nerve trunk which normally supplies the muscle, or, if this nerve trunk is totally destroyed, a branch may be made from an adjacent nerve. Thus a muscle may be brought under the domain of a nerve which never supplies it normally, for example, the biceps may be supplied by an artificial branch from the musculocutaneous, or, if the musculocutaneous is destroyed, it may be innervated by an artificial branch from the ulnar or median nerve.

- 4 Evidence that paralyzed muscles may be neurotized by an artificial nerve branch was shown by electric stimulation of the artificial nerve branch, resulting in a rapid and quick contraction of the muscle, by the normal size and color of the muscle, and by the histologic findings, which revealed normal striations in the muscle fibers. The presence of nerve branches and nerve fibers in the muscle thus innervated is conclusive evidence that neurotization has taken place.

# PRESERVATION OF THE FACIAL NERVE IN THE RADICAL TREATMENT OF PAROTID TUMORS \*

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Since in our experience facial paralysis has been a common sequela following the removal of malignant tumors of the parotid, we present herewith a description of our technic in removing the malignant parotid gland with the preservation of the facial nerve. We do not advise this radical procedure for simple encapsulated mixed tumors of the parotid, but we are in accord with Sistrunk in urging early diagnosis and early operation in such cases. However, we believe that there is need for a surgical procedure which will permit the complete removal of the parotid gland when these tumors have broken through their capsules into the parotid tissue. It must also be borne in mind that this radical operation should be performed if there is any doubt concerning metastasis from the encapsulated tumor into the parotid gland. Surgical measures should be instituted before the metastasis becomes so extensive as to break down the parotid gland and invade the cervical lymph glands, as it is extremely difficult to preserve the facial nerve when the lines of cleavage have been destroyed. In one case we found that the facial nerve had been invaded by malignant cells, producing a facial paralysis which made preservation of the nerve impossible. This emphasizes the fact that it is better to err on the side of safety by completely removing the parotid gland when in doubt concerning the malignancy of an apparently benign mixed tumor, than to perform an incomplete enucleation, leaving malignant tissue, with a broken capsule.

Volkman<sup>1</sup> believes that these tumors of the parotid are endotheliomas rising from the endothelium of the blood vessels and lymphatics. Da Costa<sup>2</sup> classifies them as endotheliomas and says that he has removed one such tumor from the tonsil, two from the nasopharynx, one from the superior maxilla and two from the parotid body. He emphasizes the point that it is not possible clinic-

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\* From the Section on General and Neurologic Surgery, Mayo Clinic

\* Read before the Western Surgical Association, Minneapolis, Dec 8, 1922

1 Volkman R. Ueber endotheliale Geschwulste, zugleich ein Beitrag zu den Speicheldrüsen und Gaumentumoren, *Deutsch Ztschr f Chir* **41** 1-180, 1895

2 Da Costa, J C. *Modern Surgery*, Ed 8, Philadelphia, W B Saunders Company, 1919 p 427

ally to distinguish with certainty these endotheliomas from ordinary sarcomas. Fraser<sup>3</sup> asserts that mixed tumors originate from the glandular structure of the salivary glands, and in his article, based on the experimental production of the neoplasm in the submaxillary gland of the dog, he concludes that mixed tumors arise from the ducts of adult glands and that injury causing partial obstruction of these ducts probably plays an important part in the production of the tumors. New<sup>4</sup> believes that, since it is impossible to demonstrate any close connection, either grossly or microscopically, between the salivary gland and the tumor, they probably do not arise from the glandular substance, particularly since the tumor, in its incipency, is surrounded by a definite capsule and appears to be situated superficially on the surface of the gland. He believes also that if trauma to the ducts of the parotid gland is a causative factor, it should be more common in the submaxillary region than in the parotid, since the submaxillary ducts are more commonly affected by salivary calculi and acute and chronic inflammatory conditions than are the parotid gland and Stenson's duct. Certain pathologists believe that they originate from fetal rests in the parotid which are encapsulated and which gradually grow. Wilson and Willis,<sup>5</sup> after a study of tumors of this type, obtained from operations in the clinic, concluded that they are mesotheliomas. Still others believe them to be carcinomas and basal-cell epitheliomas. The tissue on the interior of the capsule of such tumors varies, a few being composed chiefly of epithelial elements, others have a large amount of fibrous tissue, while in others tissue resembling cartilage seems to predominate. It is not unusual to find all three of these tissues represented in the same tumor. Such tumors are not confined to the parotid alone, but are found in the larynx, pharynx, palate, upper lip, sublingual region, cheek and submaxillary regions. In New's series of sixty-eight cases, fifty of the tumors were of the parotid, one of the larynx, four of the pharynx, three of the palate, three of the upper lip, one of the cheek, one of the sublingual region and five of the submaxillary.

Mixed tumors of the parotid constitute a very small percentage of malignant tumors of the body. Sistrunk<sup>6</sup> found that they occurred in 0.062 per cent, or one in every 1,607 patients who were examined in

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3 Fraser, A. Mixed Tumors of the Salivary glands. A Study Based on the Experimental Production of Neoplasm in the Submaxillary Gland of the Dog, *Surg., Gynec. & Obst.* **27** 19-39 (July) 1918.

4 New, G. B. Mixed Tumors of the Throat, Mouth and Face, *J. A. M. A.* **75** 732-735 (Sept. 11) 1920.

5 Wilson, L. B., and Willis, B. C. The So-Called "Mixed" Tumors of the Salivary Glands, *Am. J. M. Sc.* **143** 656-670, 1912.

6 Sistrunk, W. E. Mixed Tumors of the Parotid Gland, *Minnesota Med.* **4** 155-160 (March) 1921.

the Mayo Clinic from 1915 to 1919 The incipient growth is a painless, small round, or irregular, firm tumor in the parotid region, and is usually discovered accidentally If the tumor is left alone, the extent of its growth varies In some instances, it is rather rapid, in others, the tumor does not seem to change in size for a number of years But, sooner or later, it enlarges to a noticeable size, and the patient is then likely to consult a physician Such tumors may exist for years (forty in one case) or only for a few weeks, but when they take on new growth the problem becomes serious, for sooner or later the capsule will break and the parotid gland be invaded As long as the tumor remains encapsulated, it is not highly malignant, but when its capsule is ruptured through growth, or through an incomplete operation in which the entire tumor is not removed, invasion of the surrounding tissue soon takes place, and the growth becomes highly malignant Sistrunk emphasizes the importance of early diagnosis and early operation in cases of incipient tumors He says that complete removal of the growth at this stage will be followed by permanent cure in practically every instance We concur fully in this, but we wish to emphasize the importance of complete removal of the parotid gland if there is any possibility of not being able to make a clean enucleation of an apparently benign tumor, or if there is any evidence of an extension of the tumor through the capsule into the parotid gland, rather than waiting for recurrence Radium is, no doubt, of distinct value in treatment, but its effects do not compare with surgical measures in the treatment of these tumors, since they are not highly malignant at the outset

#### OPERATION

Sistrunk calls attention to the importance of exposing the facial nerve before removing an encapsulated tumor of the parotid gland He locates the facial nerve by first isolating the inframandibular branch of this nerve as it runs along the angle of the jaw and over the facial vessels He then follows the inframandibular branch upward through the substance of the parotid gland to the point where the facial nerve divides into the temporal and cervical branches The lower lobe of the parotid is then elevated, and the finger introduced between the parotid and the nerve He further asserts that the surgeon may feel sure that enucleation is being carried on in a plane lying above the nerve, and, although a temporary paralysis generally occurs from trauma to the nerve, it usually disappears within a year We have found that it is possible to carry the dissection of the temporal and cervical portion of the seventh nerve through the parotid and on the muscles of the face by elevating the remaining portion of the parotid

gland and dissecting the nerve away from the gland. This is possible by making an additional incision downward from the zygoma, just in front of the ear, but behind the parotid gland. The incision intersects the curved incision that has been made to identify the inframandibular branch of the seventh nerve. The latter incision extends from 3 cm upward and posterior to the lower tip of the mastoid process and runs 2 cm below the lower border of the mandible, ending 4 cm anterior to the angle of the jaw. After this incision has been made



Fig 1—Incision for the removal of the parotid gland

through the skin, the inframandibular branch of the seventh nerve should first be exposed and then dissected upward until the temporal and cervical divisions of the facial nerve are exposed. The dissection should then be carried from above downward in the line of the incision from the zygoma, and should be deep enough to expose the mandible, the temporal vessel and the posterior border of the masseter muscle. At first this dissection should be made through a narrow field to

avoid injury to the temporal branches of the facial nerve, until one is able to connect this surgical field with that exposed by the cervical incision described above. The next step is a dissection of the cervical and temporal divisions of the seventh nerve through the parotid. It is surprising to learn that the facial nerve penetrates the lower lobe of the parotid only for a distance of approximately 2 cm, after which the nerve lies underneath the parotid on the muscles of the face. From this point, the parotid together with the skin may be elevated,

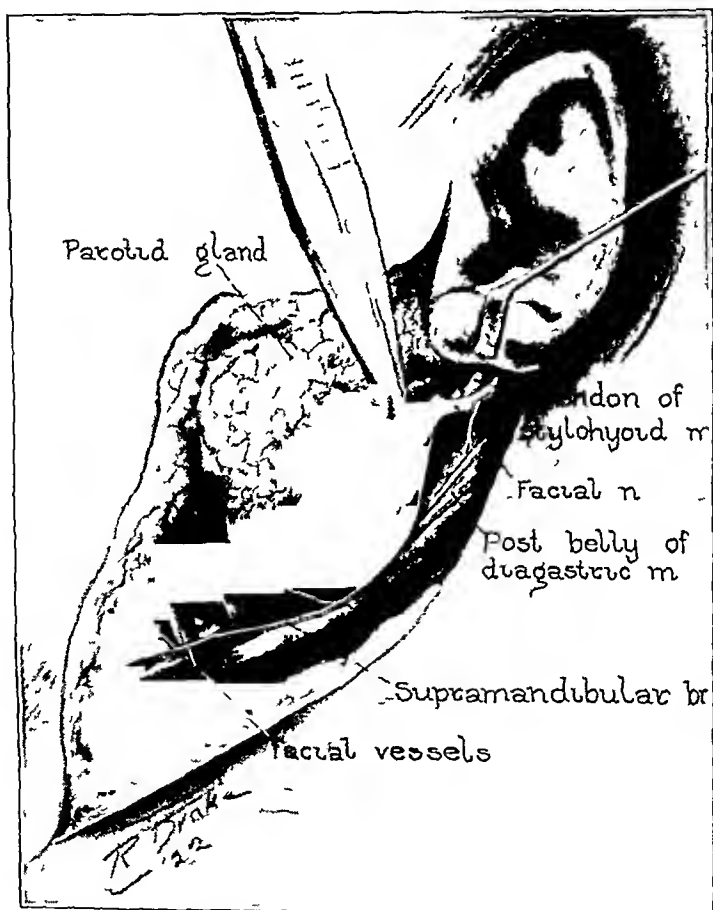


Fig 2—An elevation of the inferior lobe of the parotid exposing the facial nerve with its main divisions and the supramandibular branch

leaving the peripheral branches as they lie undisturbed on the facial muscles. The dissection is then carried forward sufficiently to elevate all of the parotid, and, when this is completed, Stenson's duct is ligated and divided and the parotid gland removed from the skin. If a skin area is involved, the involved area may be removed with the malignant mass. The deep lobe of the parotid which lies posterior and mesial to the ramus of the mandible is removed by gently elevating



the facial nerve outward and dissecting out the parotid gland which lies mesiad to it. The exposure obtained by the foregoing procedure facilitates complete removal of all parotid tissue with any involved skin that may be present, without severing or injuring the facial nerves. The dissection must be done gently, and traction should not be exerted on the nerve nor should it be handled with heavy forceps. It can be elevated gently and the nerve trunks may be lifted with dural forceps,

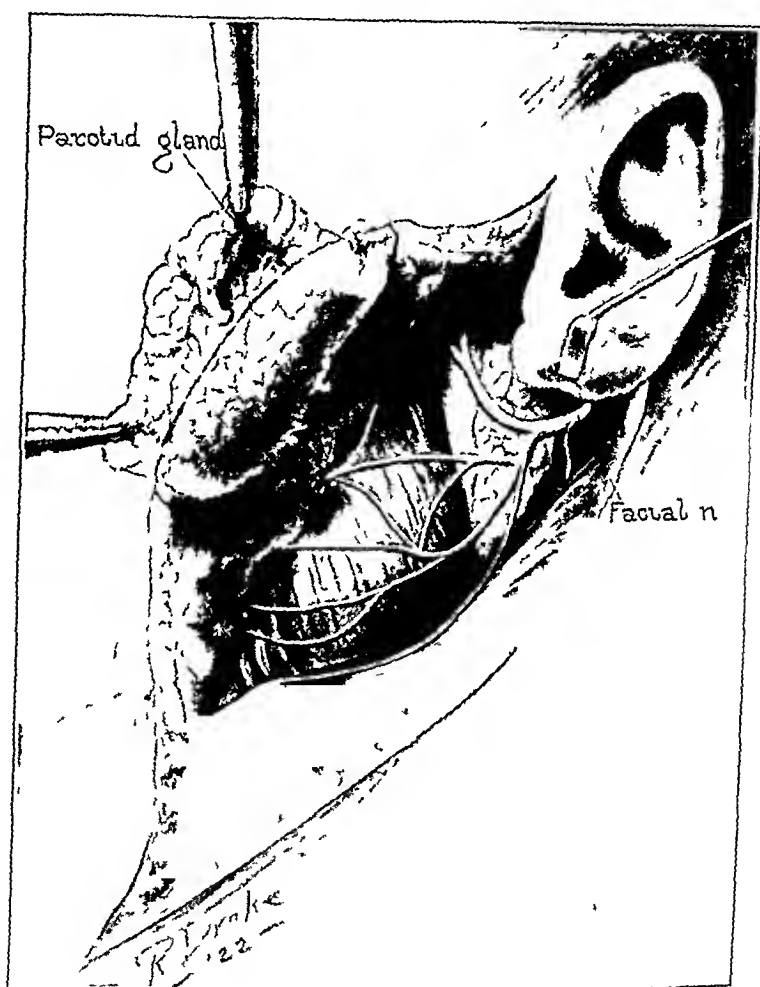


Fig. 3—The facial nerve passing through only a small portion of the parotid after which it lies on the muscles underneath the parotid gland

care being taken to apply the forceps to the perineurium. Occasionally, slight difficulty is encountered in handling the temporal artery, as it lies just in front of the ear, under the border of the parotid gland, and passes downward and inward underneath the temporal and cervical divisions of the seventh nerve. Caution should be exercised to keep the incision made from the zygoma downward close to the cartilage of the ear, and to carry it just in front of the tragus down to the

lobule, curving it backward and upward to meet the incision which extends from the mastoid below the mandible, thus avoiding any necrosis which might take place from a too pointed flap of skin just below the ear. A better exposure is obtained if a few of the fibers of the sternomastoid are divided on the anterior border at the mastoid attachment. Gentle traction on the lobule of the ear in an upward and backward direction facilitates exposure of the facial nerve. The

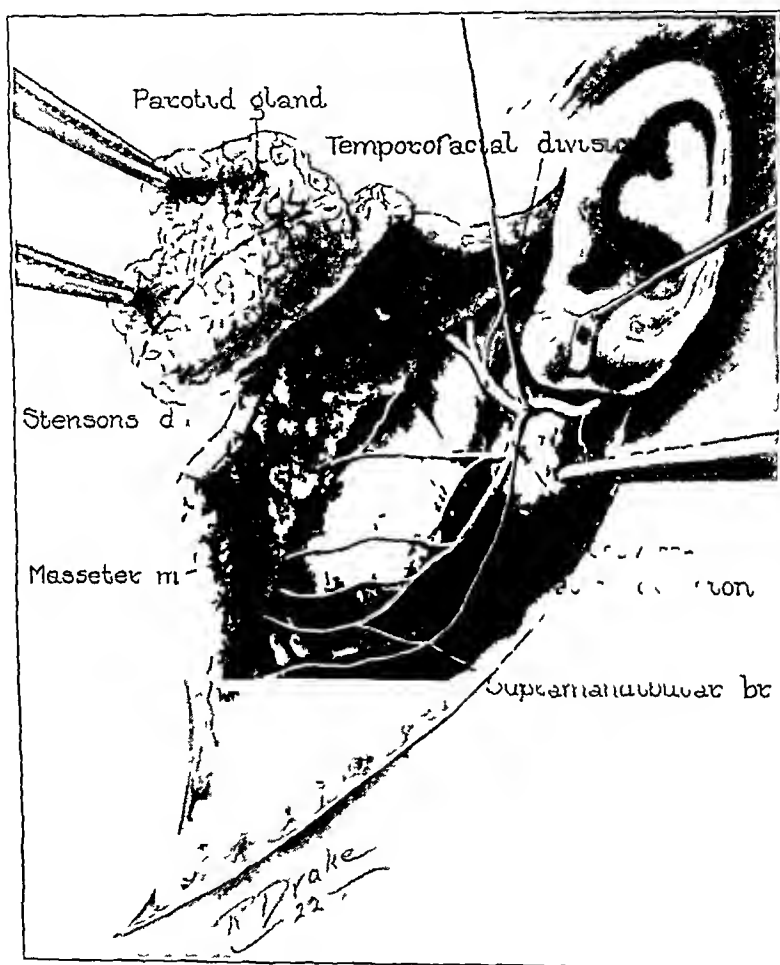


Fig 4—Preservation of the facial nerve during the removal of the posterior lobe of the parotid

wound is closed with a subareolar stitch of catgut and with a dermal stitch of horsehair. Drainage can be employed at the lower angle of the cervical wound if necessary. Every precaution should be taken to avoid sepsis or unnecessary hemorrhage by carefully preparing the field with iodine and plugging the external auditory canal with sterile absorbent cotton after the external ear has been prepared with iodine. The bleeding of the skin and parotid can be diminished by injecting

a weak solution of epinephrin along the line of the incision. Post-operative care is the same as that advised for patients on whom dissections of the neck and face have been performed (Figs 1, 2, 3 and 4)

#### SUMMARY

Early diagnosis and early and complete enucleation are advised for encapsulated tumors of the parotid gland, but, if metastasis to the gland has occurred, radical removal should be carried out with preservation of the facial nerve. The facial nerve should be sacrificed only if metastasis and necrosis have become so extensive that it is impossible to demonstrate the lines of cleavage.

# THE TREATMENT OF BRAIN ABSCESS BY THE INDUCTION OF PROTECTIVE ADHESIONS BETWEEN THE BRAIN CORTEX AND THE DURA BEFORE THE ESTABLISHMENT OF DRAINAGE

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Although medical literature is replete with reports of isolated cases of brain abscess with recovery, the percentage of recovery would doubtless be distressingly small were the full reports of all such cases made known. In reviewing the literature, one is impressed with the lack of uniformity of technic in the operative treatment of brain abscess, as well as with the lack of emphasis placed on certain fundamental principles, the observation of which is essential in order to obtain a reasonable degree of success.

In 1920, Lemaitre<sup>1</sup> called attention to the importance of walling off the subarachnoid space in the treatment of brain abscess. Since the publication of his article, I have adopted the method described below, which has been used with a degree of success sufficient to warrant its publication.

There are two complications in the treatment of brain abscess which are responsible for most of the poor results, namely, meningitis and brain fungus. Meningitis results, as a rule, from the contamination of the subdural and subarachnoid spaces at the time of, and subsequent to, the establishment of drainage of the abscess, and brain fungus occurs when a too extensive opening has been made in the skull and dura.

The contamination of the subdural and subarachnoid spaces can be largely prevented if adhesions between the brain cortex and dura are induced before permitting the free evacuation of the abscess cavity. This can be readily accomplished provided the technic described below is rigidly adhered to. After these protective adhesions have been formed, free drainage can be accomplished without fear of meningeal contamination, a principle which has been recognized for many years in the treatment of abscess of the liver, lungs, etc.

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<sup>1</sup> Lemaitre, F. Walling Off the Subarachnoid Spaces. Its Application to the Treatment of Cerebral and Cerebellar Abscesses of Otitic Origin and Also in a General Way to Surgery of the Brain, *Ann Otol, Rhinol & Laryngol* 29 1 (March) 1920.

Brain fungus can hardly occur unless an opening is made in the skull and dura, of a size sufficient to allow the brain to protrude. If the necessary opening is made just large enough to permit the entrance of the exploring needle and for the small drains to follow, the brain meets a natural barrier instead of an opening and cannot, therefore, escape.

#### TECHNIC OF OPERATION

Before selecting the point of attack, every reasonable method for accurate localization should be used. An entrance through contaminated areas (frontal sinus or mastoid) should be avoided for two reasons. First, the diagnosis of abscess may prove wrong, second, the abscess, if present, may not be reached with the exploring needle. By taking this precaution, the danger of producing an infection of the cranial contents will be obviated.

The incision should be just long enough to permit the entrance of a perforator and small burr. It should be made as nearly as possible over the suspected site of the abscess. After a small opening has been made through the skull, the dura is incised, the incision being just long enough to assure the operator that a cortical vessel will not be injured by the exploring needle. An ordinary straight ventricular puncture needle, with centimeter markings, is then inserted in the direction of the suspected abscess. As soon as the abscess is reached and a few drops of pus have escaped into a sterile test tube, the needle is withdrawn slightly until the pus ceases to appear. The exact depth and direction of the needle are then calculated.

The prevention of the free escape of pus at the time of operation cannot be too strongly emphasized. In the first place, a contamination of the wound is to be avoided, a condition which can hardly be prevented if the pus is allowed to escape freely through and around the needle. In the second place, the thorough evacuation of the contents of the abscess at this time may relieve the increased intracranial pressure to such an extent as to allow the brain cortex to lose its firm contact with the dura at the point of incision and to permit infection of the neighboring meninges. Such a spread of the infection can be prevented if the cortex becomes firmly adherent to the dura around the dural opening before free drainage is established.

After the depth and direction of the abscess have been calculated, the needle is entirely withdrawn, and a small filiform drain of folded rubber tissue is inserted down the track of the needle in the direction of, but not into, the abscess. The wound is then covered with a properly fitted dressing, which is not changed for two or three days. During this time, the rubber tissue wick, acting as a foreign body, stimulates the formation of adhesions between the brain cortex and the dura, forming a well-defined ring around the drain. At the first dressing, the wick

may be inserted into the abscess. This usually causes very little drainage unless the pus is under great tension. Two days later, the second dressing may be performed, and a second small rubber tissue wick inserted down the track along the side of the first. The dressings may then be changed daily, for by this time the protective adhesions are widespread and firm enough to permit the gradual enlargement of the drainage track by means of additional small wicks of rubber tissue. Within a week or ten days, it is safe to withdraw these wicks and to substitute a drainage tube (preferably the eye portion of a No. 10 English rubber catheter) down the well-formed drainage track into the abscess. Usually, free drainage does not take place until tube drainage is established. The dressings from this time may be performed as frequently as desired, the tube being removed and cleansed if suspected of being clogged with exudates. No undue haste in permanently withdrawing the drain should be practiced. As long as there is any drainage whatsoever, the tube should be kept in situ and only removed permanently when all evidences of the infection have subsided. It is a safe practice to leave the tube inserted for a week or ten days after active drainage has ceased, and gradually withdraw it by daily shortening. It may be two or three months before the drainage tube may be dispensed with, although the average case does not require such a long time.

#### REPORT OF ILLUSTRATIVE CASE

The following case of a small series has been selected to illustrate the value of the method of treatment described above.

#### HISTORY

M. D., aged 17 years, referred by Dr. C. A. Thigpen of Montgomery, Alabama, was admitted to the Piedmont Sanatorium, July 28, 1922. June 27, the patient first consulted Dr. Thigpen, whose letter concerning her condition is as follows: "On the evening of June 27, she was brought to me in a prostrate condition. What attracted attention at first inspection was a closed right eye with much edema and exophthalmos, the typical picture in children of acute fronto-ethmoiditis. Temperature was 103 F., pulse 120. I operated without delay, making a brow incision. The right frontal sinus was small but filled with thick creamy pus and some granulations. At the same time, I removed the anterior end of the right middle turbinate, broke down the anterior ethmoid cells and established free communication with the frontal cavity. Relief was prompt, the temperature and pulse gradually returning to normal, headaches ceased, and, on the ninth day, she was able to leave the hospital. About a week later, she began to have increased temperature and a return of the headaches, necessitating the reopening of the frontal wound and the curetting away of the granulations. The wound has been kept open ever since. The improvement was again prompt and continued so until three days ago when she went into a state of collapse, with slow pulse, cool extremities, etc. At this time, the optic disks were beginning to show evidence of increased intracranial pressure. I, therefore, have made a diagnosis of brain abscess." She had suffered from fairly constant

headaches, excepting for a few days following the operations, since the onset of the present illness. They had been located principally in the right frontoparietal region. Vomiting, projectile in character, had occurred several times during the preceding week. Double vision, lasting two days only, had occurred five days previously, but was not present at the time of examination. Three or four attacks of dizziness, momentary in duration, had occurred during the previous two weeks, causing her to grasp an object to keep from falling, and had been relieved by lying down. The family history was unimportant, except for arrested "lung trouble" in the mother. The patient had had influenza five years previously, the usual diseases of childhood, and tonsillitis, four years previously.

#### NEUROLOGIC EXAMINATION

*Head*—There was an operation scar, with a small discharging sinus (mucopurulent), on the right side of the bridge of the nose, slight, though definite, dilatation of the veins over the right frontal region, slight edema of the upper eyelids, more marked on the right than on the left. The veins of the upper right eyelid were quite prominent. Both eyes showed a mild degree of exophthalmos, more marked on the right than on the left.

*Cranial Nerves*—The retinal veins were greatly engorged. The optic disk was completely obliterated, presenting the picture of a recent, though definite chloking. The same conditions obtained on the left as on the right, though to a less marked degree. There was a moderate degree of photophobia on both the right and left sides. No changes were found in the visual fields. The pupils were equal, and reacted to light and in accommodation. All external eye movements were well performed, except when the patient looked to the extreme left. There was no nystagmus. Voluntary and emotional movements of the face were slightly sluggish on the left, as compared with the right. All other cranial nerves functioned normally.

*Cerebrum*—There was a fine tremor of the outstretched fingers of the right hand, and no disturbance of memory, except in regard to the recent operation, concerning which the patient had no clear remembrance. There was no frank disorientation. The patient was right-handed. There was no aphasia, no uncinate gyrus symptoms, and no hemianopsia. No convulsions, either general or localized, had occurred. There was no paralysis nor weakness of the various groups of muscles of the extremities on the right or left. Slight weakness of the left facial muscles was observed. Ankle clonus was not obtained either on the right or left. No sensory disturbances were observed on the right or left. There was no astereognosis or disturbance of joint sense.

*Cerebellum*—No asynergia was demonstrated on the right or left. There was no nystagmus.

*Reflexes*—The abdominal and epigastric reflexes were active and equal on the two sides. The arm reflexes and knee jerks were hyperactive on the right and highly exaggerated on the left. The Achilles jerk was hyperactive on the right and highly exaggerated on the left. Babinski, Gordon and Oppenheim reflexes were absent on the right and left. Kernig's sign was absent on the right and left.

*Sphincters*—There was no disturbance of the sphincters.

#### GENERAL EXAMINATION

*General Condition*—At the time of examination, the pulse was 64, the blood pressure systolic, 98, diastolic, 50, and pulse pressure, 48.

*Urinanalysis*—The reaction was acid, specific gravity, 1.014. Albumin, sugar and indican were absent. Numerous epithelial cells, a fair number of pus cells and an occasional red blood cell were demonstrated in a noncatheterized specimen.

*Blood*—Examination revealed hemoglobin, 80 per cent, erythrocytes, 4,250,000, leukocytes, 8,900. Differential count: polymorphonuclears, 69 per cent, small mononuclears, 30 per cent, transitionals, 1 per cent.

#### COMMENT

The development of symptoms and the finding of increased intracranial pressure subsequent to a verified suppurative fronto-ethmoiditis were strongly suggestive of brain abscess. The headaches on the right, the greater choking

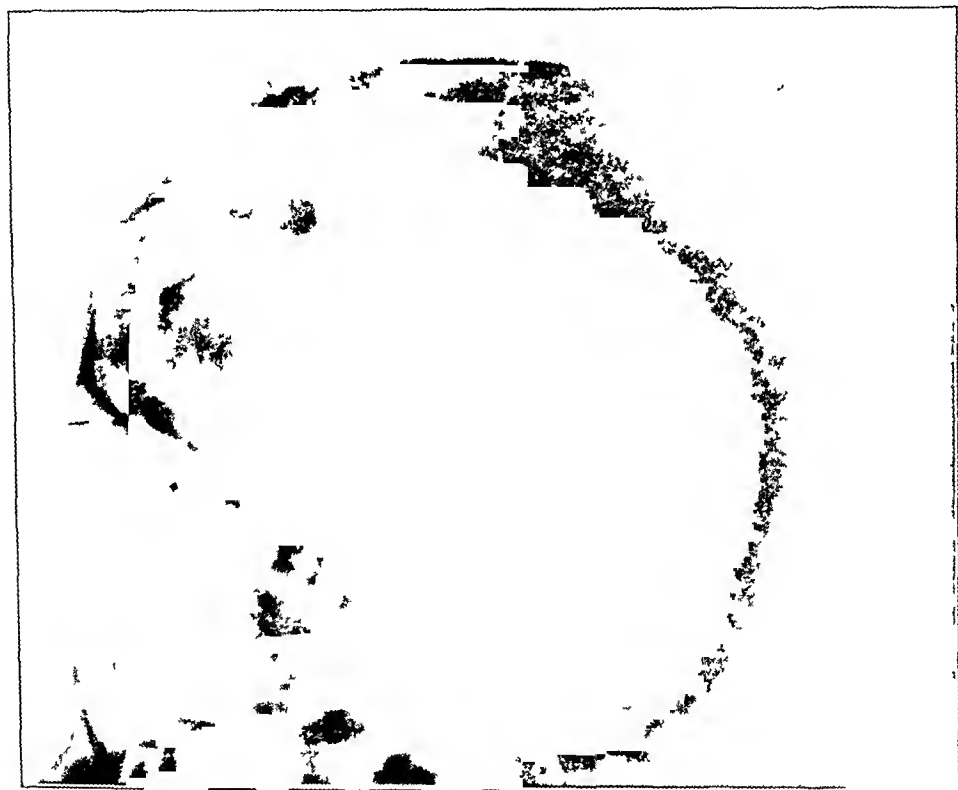


Fig 1—Lateral view of skull with grooved director passed through the opening in the skull, down the drainage track into the abscess.

of the right optic disk than of the left, the fine tremor of the outstretched fingers of the right hand, the exaggerated deep reflexes on the left, and the slight weakness of the left facial muscles suggested that the most likely site of the abscess was the right frontal lobe.

#### OPERATION

Under local anesthesia, induced by 1 per cent procain-epinephrin solution infiltration, an incision, 2 cm long, was made along the hair line in the right midfrontal region. The opening into the skull was accomplished with a perforator and small burr. An incision, 0.5 cm long, was made in the dura



Through this small opening, a straight ventricular puncture needle was passed through the cortex of the brain, downward, slightly forward and medially. At a depth of 3 cm, a slight resistance was encountered, which was interpreted as being the capsule of the abscess, or possibly the dura overlying an epidural abscess. The needle was gently pushed through the resistance, and pus escaped under great pressure. In spite of the immediate withdrawal of the needle, 10 cc



Fig 2—Postero-anterior view of skull, with the grooved director passed through the opening in the skull, down the drainage track into the abscess

of pus had escaped into a sterile test tube before the flow was stopped by withdrawing the needle. A small filiform wick of folded rubber tissue was then inserted down the track of the needle, to the capsule but not into the abscess. The edges of the scalp wound were whipped over with continuous catgut in order to control hemorrhage and a plain gauze dressing was applied

## DIAGNOSIS

There was a large abscess at the base of the right frontal lobe, 3 cm below the cortex, at the site of the incision. The pus was thin and greenish. Culture revealed *Staphylococcus aureus*. The brain was under greatly increased tension.

## COURSE

July 29, 1922 The dressing was changed, but the drain was not disturbed. Practically no drainage had occurred, and the general condition was good.

July 31 The dressing was changed, and a drain was inserted for 0.5 cm, causing an immediate escape of a moderate amount of pus. The temperature and pulse were normal. There was no evidence of meningitis and no change in the disks. The headaches were not so severe, but they had not been completely relieved.

August 2 The dressing was changed. Drainage had saturated several thicknesses of gauze, but the flow was not free. The drain was manipulated slightly but was not changed. The condition of the patient was excellent.

August 4 The dressing was changed. A slightly larger rubber tissue wick was substituted for the one inserted at the time of operation. Drainage was satisfactory, though not very free.

August 5 to 9 Daily dressings were performed. Drainage was fair but not abundant.

August 10 The drain was removed, and a grooved director was inserted through the drainage track into the abscess. As soon as this was done, fully 30 cc of pus escaped. A roentgenographic examination was made with the director inserted into the abscess (Figs 1 and 2). The director was withdrawn, and a very small rubber catheter drain was inserted into the abscess.

August 12 There was no drainage. The tube was removed, and a No. 10 English rubber catheter drain was inserted, causing immediate free drainage.

August 13 to 24 Daily dressings were performed. Abundant drainage had occurred, which had gradually become less and less. The patient had no symptoms.

August 25 to September 17 The dressings were changed every three or four days. At each dressing, the tube was shortened slightly. Practically no drainage had occurred. The tube was removed completely, September 17.

September 24 The patient was discharged from the hospital. The wound was healed. All symptoms and neurologic findings were absent. Her condition was excellent.

October 4 A letter from Dr. Thigpen was received to the effect that the patient was in excellent condition and apparently cured.

## COMMENT

This case is reported fully because it is a typical illustration of what should be expected in most cases of single abscess of the brain, when the abscess can be located with the exploring needle. Large openings into the skull and dura with the immediate establishment of free drainage, I believe, are responsible for the majority of poor results in this type of lesion, as the development of meningitis and brain fungus are to be expected under such conditions. If preformed adhesions between the dura and cortex are present, immediate drainage might be effected with safety. Such a condition, however, is rarely encountered, except in

cases of abscess following injury caused by some foreign body. If protective adhesions are not already present, they should be induced before free drainage is established.

Decompression in cases of brain abscess is particularly to be condemned. As soon as the increased intracranial pressure under such circumstances is relieved by decompression, there is a tendency for the abscess to be dislocated in the direction of the decompression, thereby promoting further destruction of brain tissue, which should not occur if the abscess is drained through a very small opening in the skull.

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# PRIMARY LYMPHOSARCOMA OF THE PROSTATE

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In the pathologic laboratories of Bellevue Hospital, I have recently studied a primary tumor of the prostate with the characteristic structure of a lymphosarcoma. With the exception of an almost identical growth recorded by Coupland,<sup>1</sup> I have been unable to find an acceptable description of another primary lymphosarcoma of the prostate in the literature. However, these two cases are so clearly defined that they remove all doubt as to the possibility of lymphocytic tumors' arising in the prostate. It remains to be shown by future investigation just how common such tumors are. I suspect that they are not so rare as the literature would indicate, and, indeed, I believe that lymphosarcoma should always be considered a possibility in patients under 35 years of age with prostatic tumors. The recognition of this type of growth in the prostate is peculiarly important in view of the favorable results that have been recorded by the roentgen-ray and radium treatment of lymphosarcomas in other parts of the body.

Coupland's case was that of a man, 29 years of age, who complained of pain at the point of the penis and an almost constant desire to micturate, passing only a few drops of urine at each time. The urine contained a large quantity of pus. Rectal examination was painful and revealed almost uniform enlargement of the prostate, which was firm but not very tender.

At necropsy, it was found that the bladder resembled a small cone with a broad base. The cavity was not much larger than a walnut and the bladder walls were thickened to the extent of about one-half inch (1.27 cm). The prostate was the seat of a new growth which was ovoid, and measured, internally, 8 inches (20.3 cm) in circumference and 3½ inches (8.9 cm) in length. The growth was fleshy in consistency and surrounded the neck of the bladder and the prostatic urethra. The pancreas was fibrotic, and, at a point corresponding to the junction of the head of the organ with the body, the glandular substance was replaced by an ill-defined, translucent, pale yellow nodule about the size of a filbert and of fleshy consistency. The right suprarenal was enlarged to about twice the normal size and was uniformly infiltrated by grayish yellow, semitranslucent, fleshy tumor material.

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<sup>1</sup> Coupland. Tr. London Pathological Society, 1877, p. 179

The histologic description of the tumor in the prostate, suprarenal and pancreas is that of a typical lymphosarcoma and was so accepted by the Morbid Growths Committee of the London Pathological Society. The illustration which accompanies Coupland's paper can scarcely leave any doubt as to the correctness of this interpretation.

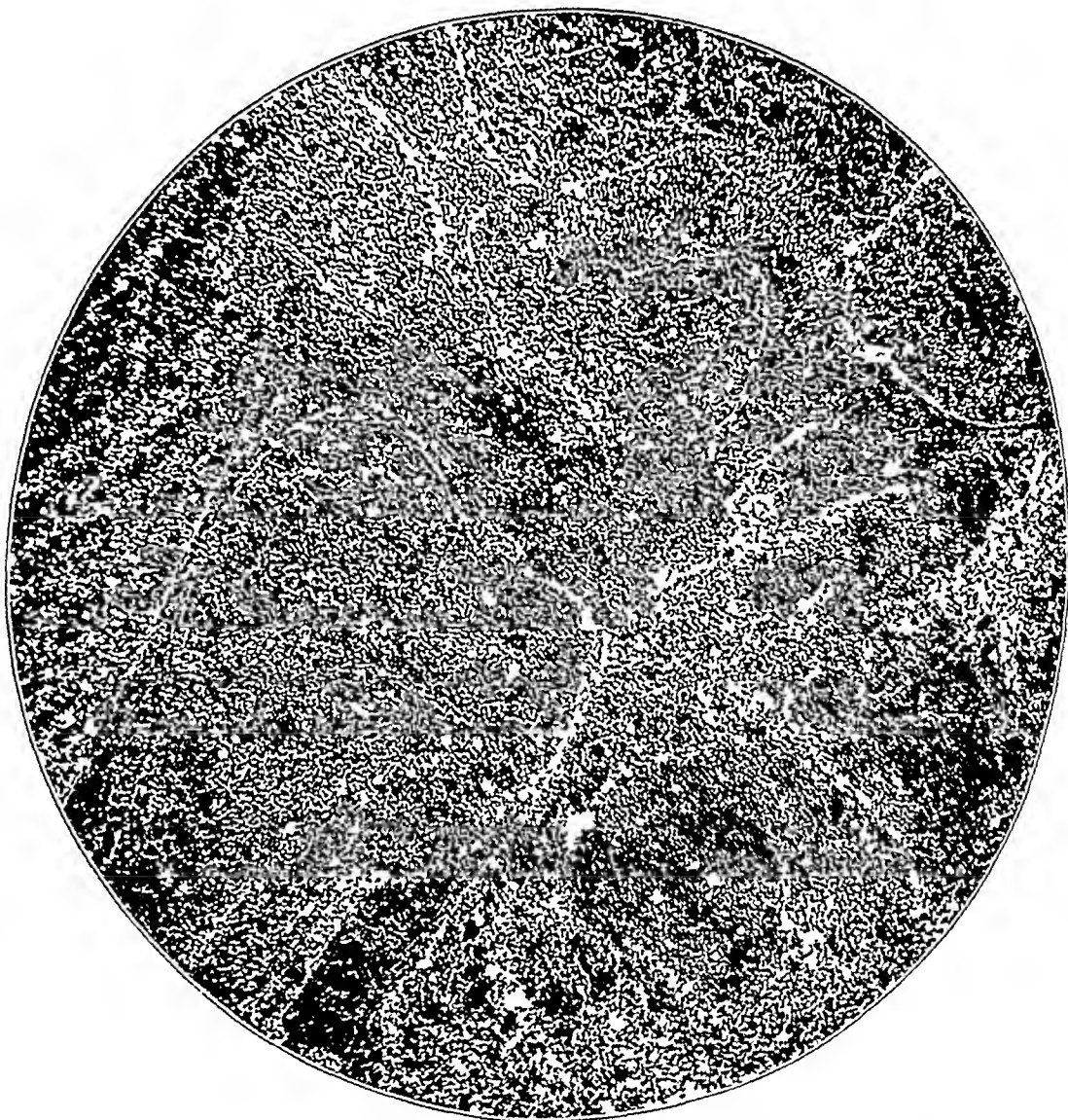


Fig 1—Low-power photomicrograph of the growth in the prostate, showing huge numbers of lymphocytes arranged in small islands, separated from one another by delicate strands of connective tissue.

#### REPORT OF CASE

*History*—A man, aged 30, born in Denmark, and from whom a satisfactory history was not obtained, was admitted, March 22, 1918, and died April 16. The patient stated that in the course of the seven weeks before admission to the hospital, he lost 20 pounds (9 kg) in weight and that lately he had become

obstinately constipated. He likewise complained of a sharp pain in the region of the left kidney that radiated downward in the direction of the corresponding iliac fossa. He, moreover, stated that it was frequently necessary for him to void urine and that, on one occasion, he had great difficulty in passing it for a period of several days.

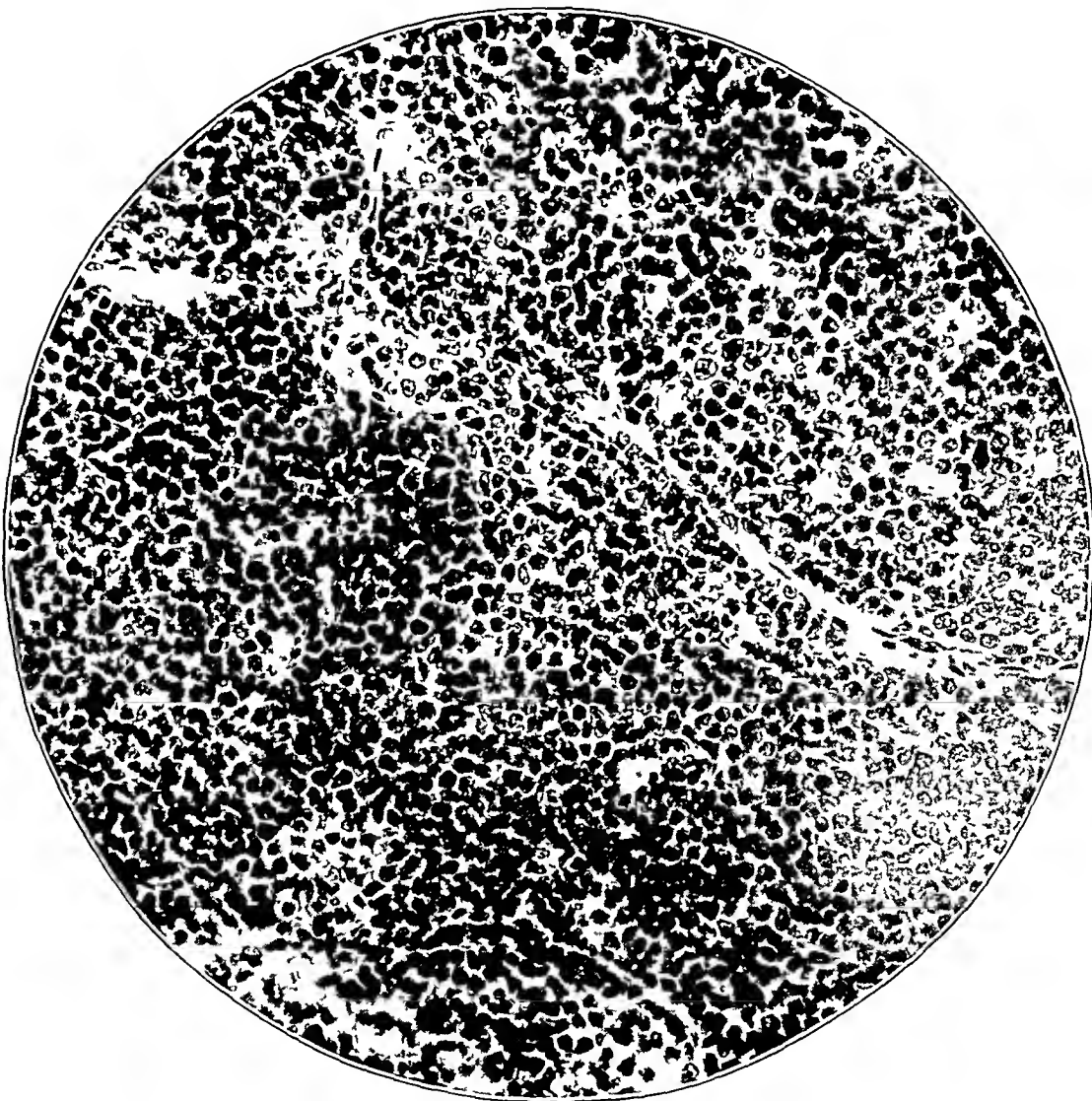


Fig 2—High-power photomicrograph of the prostatic growth

*Examination*—The urine revealed nothing abnormal other than a small number of pus cells. Roentgen-ray examination of the region of the left kidney failed to reveal the presence of a shadow suggesting a stone. The Wassermann reaction was negative with both antigens. The blood count showed 4,200,000 red cells, 70 per cent hemoglobin, 12,800 white cells of which 81 per cent were polymorphonuclear leukocytes and 19 per cent lymphocytes.

Four days after admission to the hospital, cystoscopy was attempted, but the instrument would not pass the prostatic portion of the urethra and the effort was abandoned

*Necropsy*—The body was 168 cm in length. The region of the prostate was occupied by a growth that measured 9 cm in diameter and 7 cm in length. It surrounded the posterior urethra and was continuous with the lower third of the bladder, in which locality the walls of the bladder were thickened to the

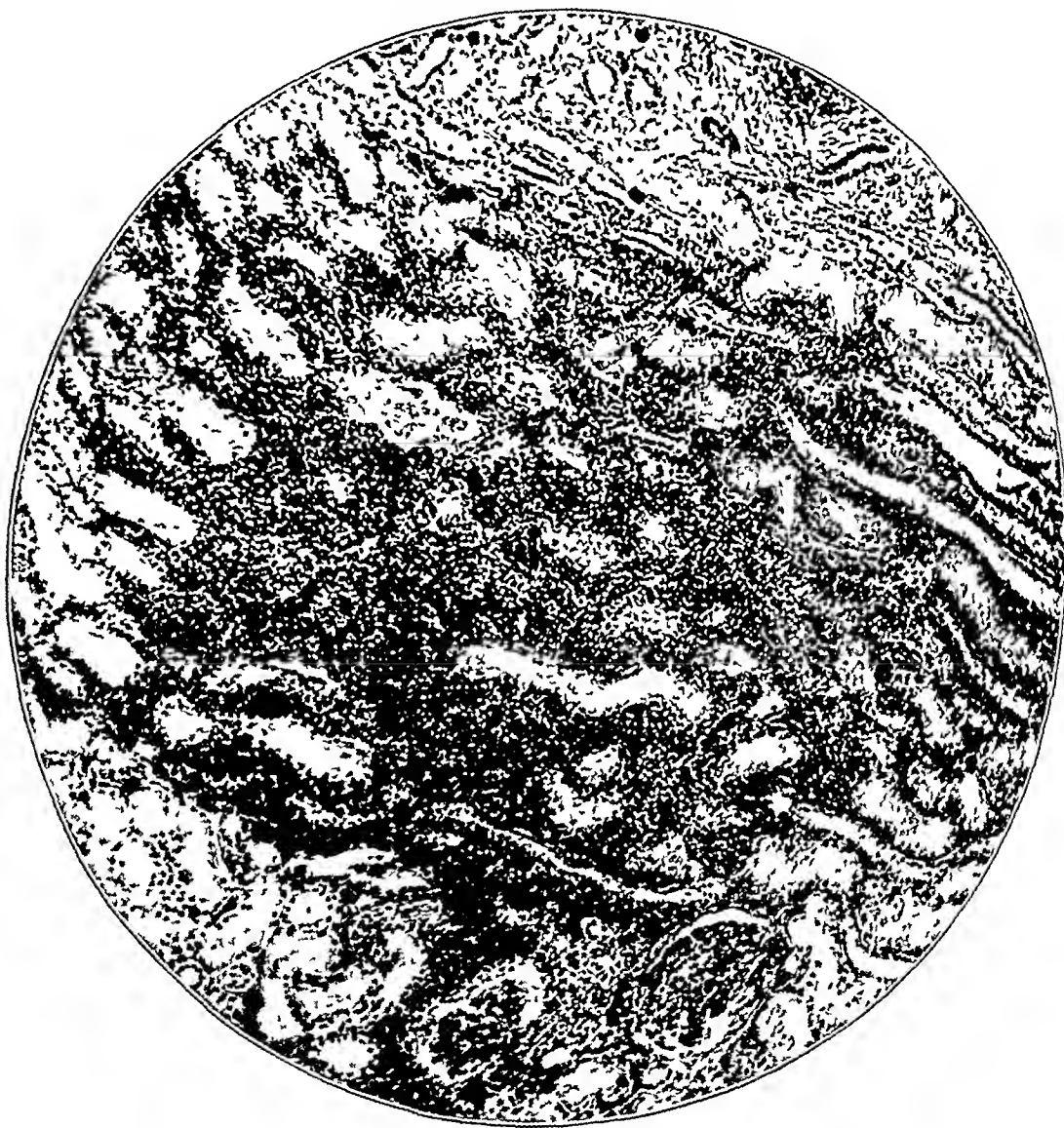


Fig 3—Low-power photomicrograph of infiltrating hordes of lymphocytes in the cortex of the kidney

extent of about 1 cm and, on section, presented a pale, smooth, cream colored surface. The thickening of the bladder wall gradually disappeared as the viscus ascended into the pelvis, so that at the fundus the thickness was about normal. The bladder was dilated, measuring 12 cm from trigon to fundus. The mucous membrane was swollen and presented numerous large and small,



velvety-looking, faintly reddish splotches. The prostatic growth presented, on section, a perfectly smooth, cream colored or whitish appearance. The substance was fairly friable. The seminal vesicles could be seen embedded in and compressed by the growth. Laterally, the growth invaded the psoas magnus muscle on both sides. The rectum was not involved. Strewn along the front of the spine on both sides, from the brim of the pelvis upward as far as the level of the pancreas, were numbers of large and small

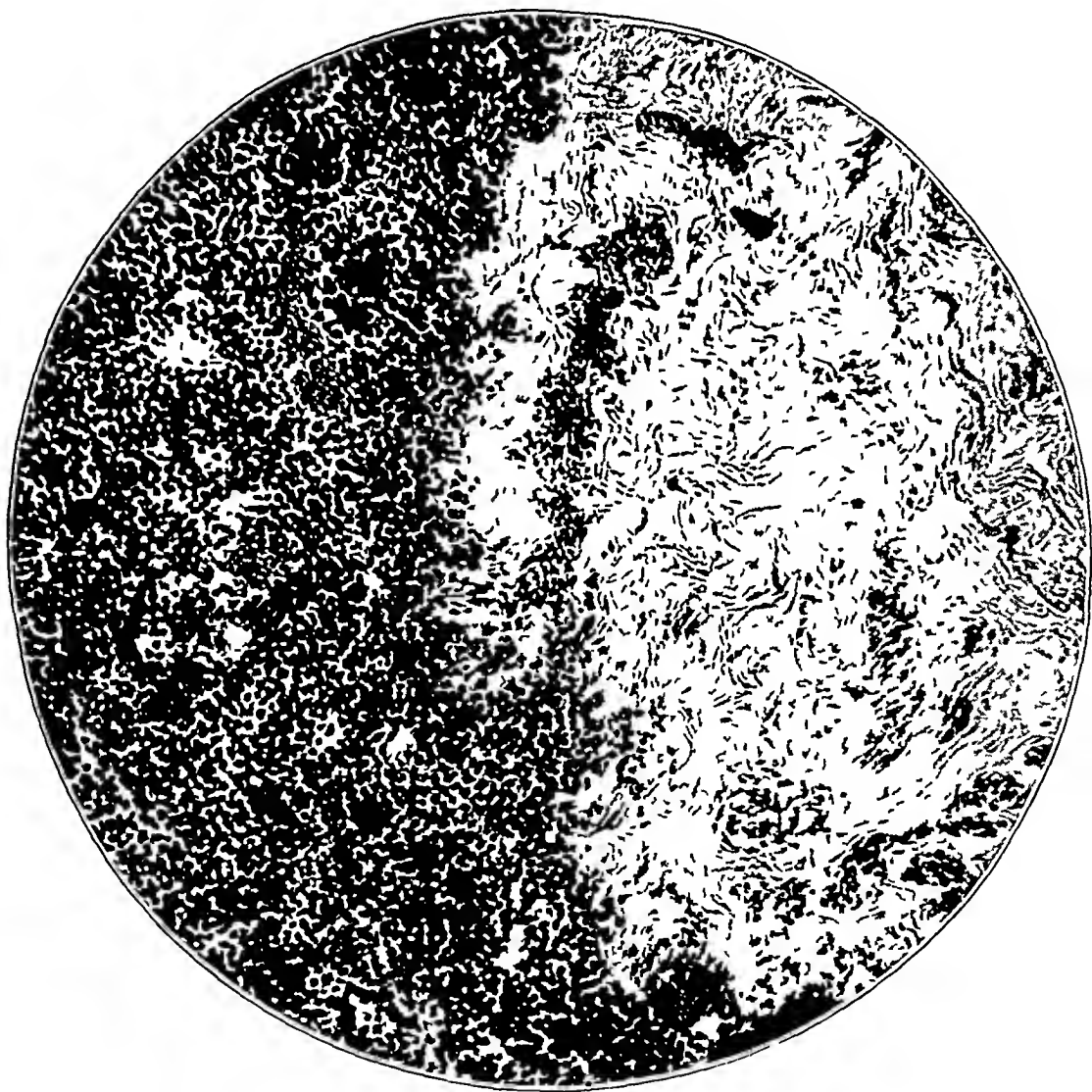


Fig 4—Low-power photomicrograph showing lymphosarcomatous infiltration of the walls of the ureter

rounded, oval or flattened nodules, some of which were discrete, others fused, that presented, on section, much the same appearance, to the naked eye, as the tumor in the prostate. The testicles were unchanged. The left kidney was considerably enlarged. Projecting beneath the capsule were a dozen or more small cream colored elevations. Similar bodies were found deep in the medul-



lary portion near the pelvis. The upper third of the ureter was twisted and dilated by fluid. The ureters on both sides ran directly through the large masses of cream colored tumor tissue that lay at the side of the spine. The left suprarenal capsule was buried in tumor tissue of much the same general appearance as that in the prostate and elsewhere. The liver was enlarged. Beneath the capsule, and scattered over the cut surface, were large numbers of grayish or slate colored streaks or patches, between which the liver tissue was

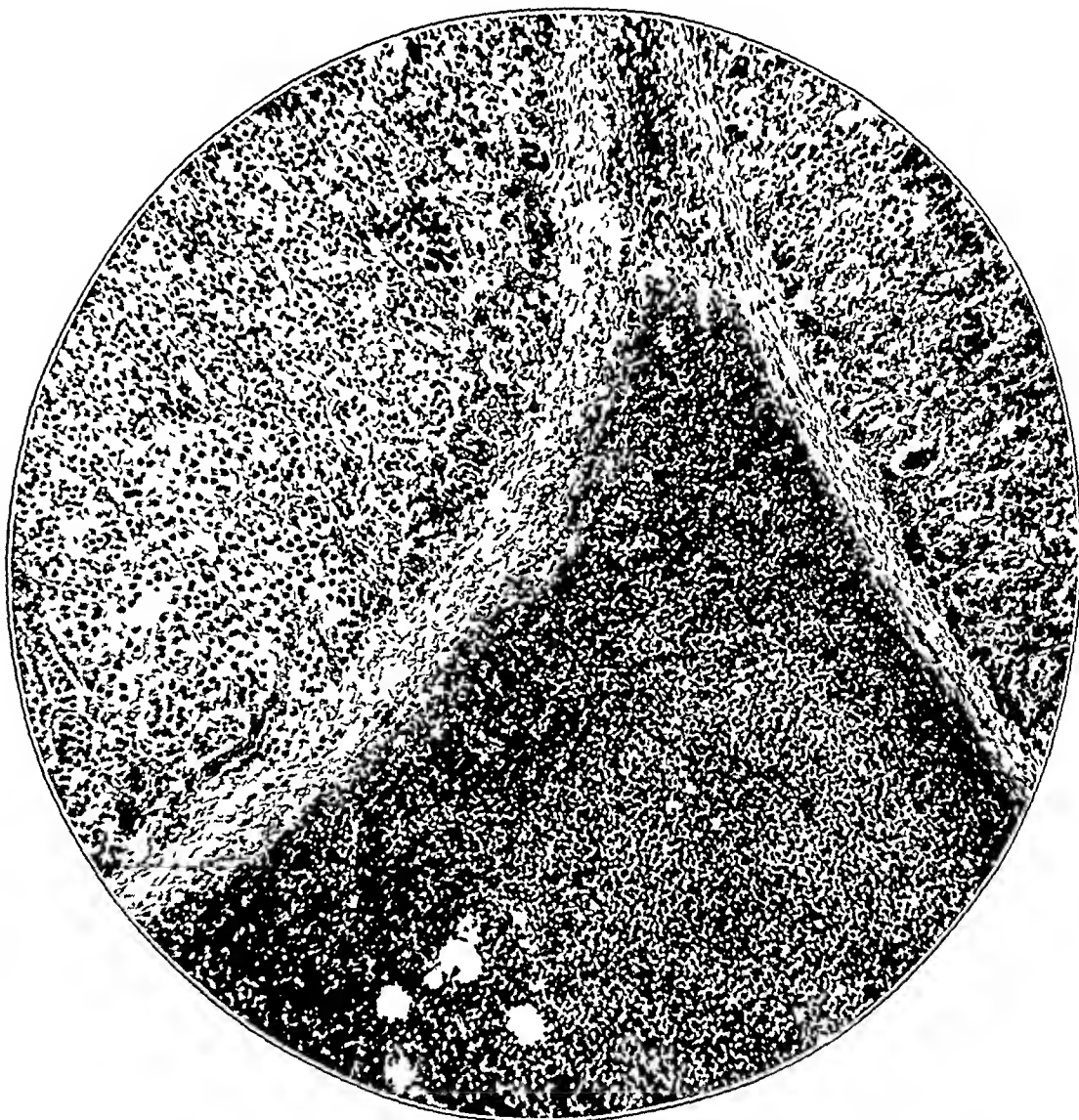


Fig 5—Low-power photomicrograph showing lymphosarcomatous infiltration of the tissues around the suprarenal capsule

faintly brownish in color. Under the pleura on the left side, corresponding to the upper border of the fifth rib in the midaxillary line, was a small oval cream colored nodule. The pleura covering it was intact, as was the border of the rib against which it lay. The remaining organs showed nothing worthy of note in the present connection.

*Anatomic Diagnosis* — This was massive lymphosarcoma of the prostate, with extensive infiltration of both psoas magnus muscles, and compression of the seminal vesicles, bilateral neoplastic infiltration of the retroperitoneal lymph nodes and of both kidneys, with dilatation of the ureters and periureteral neoplastic infiltration, neoplastic infiltration of the liver, solitary metastatic deposit in the left parietal pleura

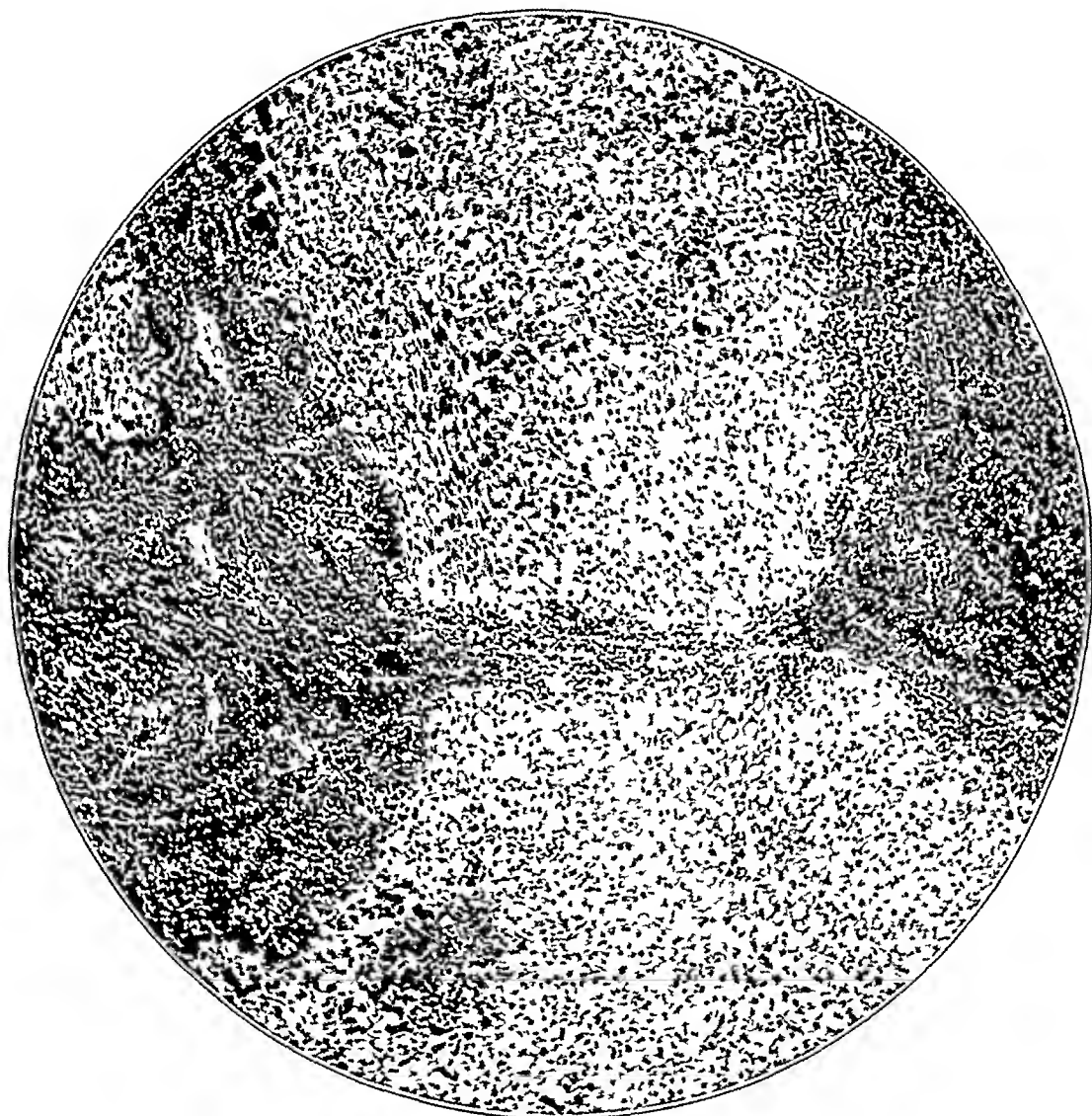


Fig 6—Low-power photomicrograph showing extensive lymphosarcomatous invasion of the perlobular connective tissues of the liver

*Histology*—Microscopic examination of the primary growth in the prostate revealed the presence of vast numbers of small round cells presenting the histologic characteristics of lymphocytes. For the greater part, the cells were growing diffusely but in places they were arranged in small islands separated from one another by delicate strands of connective tissue (Fig 1). Careful scrutiny of

microscopic sections from the original growth, as well as from its secondary deposits, failed to reveal the slightest indication of glandular formations. In other localities, the histologic structure of the tumor differed in no essential particular from that of the prostate, although insular formations were not to be seen, the cells growing diffusely.



Fig 7—Low-power photomicrograph illustrating neoplastic destruction of the psoas magnus muscle

#### COMMENT

The belief that tumors composed of lymphoid cells may arise in the prostate has been challenged on the ground that the prostate is a glandular organ whose fibromuscular stroma does not normally contain lymphocytic tissue. It is maintained that the small round-cell tumors of

the prostate are in reality carcinomas, the cells of which have become so altered as to resemble lymphoid cells, and that careful search will eventually disclose in some part of all such growths a return to the glandular arrangement by which these epithelial tumors of the prostate are characterized. I am unable to subscribe to this view. It has been shown that the prostate belongs to the so-called auxiliary lymphoid system, that is to say, that, with the suprarenal capsule, thyroid, lung, liver, kidney, testicle and other organs, the prostate normally contains interstitial lymphoid foci, which, in ordinary circumstances, are likely to be overlooked, but, in certain conditions of disease, are readily identified. There is no apparent reason why a tumor of lymphoid cells should not spring from such a focus in the prostate, nor, indeed, why any one or all of the other members of this group of organs should not react similarly. That they do not more commonly give rise to lymphocytic growths is to be explained by the fact that the lymphoid rests in them are numerically insignificant and that they are functionally dormant, undergoing hyperplasia only in unusual circumstances, whereas the follicles of the lymph nodes and spleen, tonsils, gastro-intestinal tract, etc., are geographically distributed in such fashion as to serve as filters, in which capacity they are constantly engaged in the process of compensatory regeneration and hence are frequently subject to disturbances of cell equilibrium.

# THE PHYSIOLOGY OF PULMONARY EMBOLISM AS DISCLOSED BY QUANTITATIVE OCCLUSION OF THE PULMONARY ARTERY\*

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AND

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Pulmonary embolism is a condition frequently encountered in clinical practice. The picture varies from symptoms produced by multiple small emboli lodged in the lung periphery, to symptoms resulting from massive blocking of one or both pulmonary arteries. In the case of small emboli, though severe chest symptoms often result, the patient usually recovers, while in massive blocking it is commonly believed that death ensues either immediately or within a few hours.

That massive pulmonary embolism may occur without disastrous effects on the general circulation was first shown by Lichtheim<sup>1</sup>. Two years later Welch<sup>2</sup> demonstrated that ligation of the circulation to one entire lung may be accomplished without effect on the systemic blood pressure—an observation confirmed later by Plumier<sup>3</sup> and also by Gerhardt<sup>4</sup>. Tigerstedt<sup>5</sup> corroborated and extended these observations, showing, by means of the stromuhr, that occlusion of half of the pulmonary circulation decreased only slightly the minute volume output of the left ventricle. Mann<sup>6</sup> supported this evidence by making intravenous injections of wax and clots into dogs until the pulmonary circulation was largely obstructed, without affecting either blood pres-

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\* From the Laboratories of Physiology Harvard Medical School

1 Lichtheim. Die Störungen des Lungenkreislaufes und ihr Einfluss auf den Blutdruck, Inaug. Dissert., Berlin, 1876

2 Welch, W. H. Zur Pathologie des Lungenödems, Virchows Arch f path Anat **72** 375 (March) 1878

3 Plumier, L. La circulation pulmonaire chez le chien, Arch internat de physiol **1** 176, 1904

4 Gerhardt, D. Experimentelle Beiträge zur Lehre vom Lungenkreislauf und von der mechanischen Wirkung pleuritischen Ergusses, Ztschr f klin Med **55** 195 1904, Zur Lehre von der Hypertrophie des rechten Ventrikels, Arch f exper Path u Pharmacol **82** 122 (Oct) 1917

5 Tigerstedt, R. Ueber den Lungenkreislauf, Skand Arch f Physiol **14** 259, 1903

6 Mann, F. C. Pulmonary Embolism. An Experimental Study, J Exper Med **26** 387 (Sept) 1917

sure or respiration Dunn,<sup>7</sup> in 1920, was able to inject 15 c c of starch into the jugular vein of goats anesthetized with ethyl carbamate (urethan), weighing from 20 to 30 kg, without producing any effect other than a pronounced dyspnea. Histologic examination of the lungs of Dunn's animals showed "that the degree of obstruction of the pulmonary arterioles is very great."

More recently Underhill,<sup>8</sup> employing, in addition, a Schafer<sup>9</sup> pulmonary cannula, has made somewhat similar observations on cats with both open and closed chests. He reports that under artificial ventilation (chest open) ligation of the left pulmonary artery causes an average rise in pulmonary arterial pressure of about 40 per cent.

The experiments cited show clearly that a large part of the pulmonary circuit may be blocked without causing a fatality. There is, however, no direct evidence as to the exact amount of obstruction required.

Our investigation was undertaken at the suggestion of Dr C K Drinker in an attempt to observe the effect of graded pulmonary arterial occlusion upon the systemic and pulmonary blood pressures and to note possible variations in lung ventilation. The heart preparation which we employed was that recently devised by Drinker<sup>10</sup>—a preparation which affords easy access to, and control over, the heart and all the great vessels in a normally breathing animal, and permits experimentation in this region under conditions more closely approaching the normal than has heretofore been possible.

#### TECHNIC

The animals employed were cats, ethyl carbamate, in the majority of the experiments, being the anesthetic used. Because of the possible depressing effects of this drug upon the respiratory center, a few control experiments were performed under ether, but so far as the experimental results are concerned there was no essential difference.

The operative technic may be briefly summarized as follows. Under artificial respiration an oval area in the chest wall, immediately over the heart and roughly corresponding to its size, is removed, and hemostasis obtained. The pericardium is then incised longitudinally

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7 Dunn, J S. The Effects of Multiple Embolism of Pulmonary Arterioles, *Quart J Med* **13** 129 (Jan) 1920, The effects of Multiple Pulmonary Embolism, *J Physiol (Proc Physiol Soc)* **53** 5 (May) 1919.

8 Underhill, S W F. An Investigation Into the Circulation Through the Lungs, *Brit M J* **2** 779 (Nov) 1921.

9 Schafer, E S. A Convenient Method of Recording Pulmonary Blood-Pressure, *Quart J Exper Physiol* **12** 133, 1918-1920.

10 Drinker, C K. A Useful Heart Method. *J Exper Med* **33** 675 (June) 1921.

and the cut margins are sewed to the edge of the chest wall with interrupted sutures. The air imprisoned in the chest cavity is then aspirated and the pleural cavity rendered air-tight. Negative intrathoracic pressure having thus been restored, artificial respiration is stopped, and the animal is permitted to breathe naturally. In one instance an animal, prepared in this manner and maintained under complete anesthesia

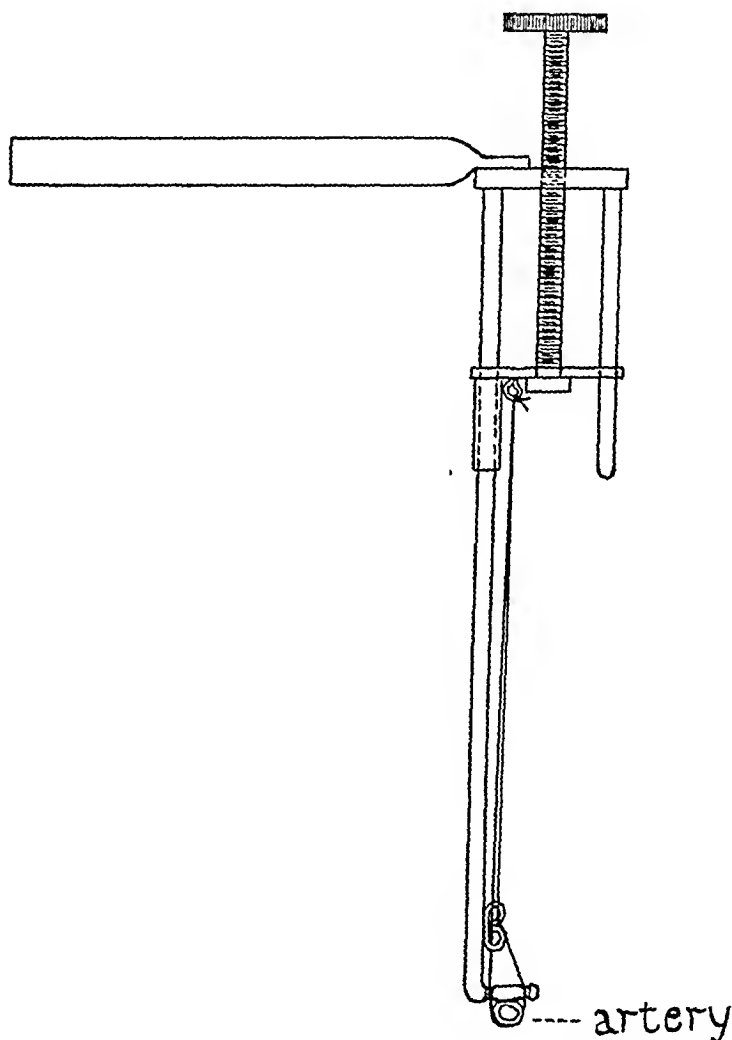


Fig. 1—Clamp A, used for compression of the pulmonary artery and its left branch

on a warm table, lived through the night and was used for experiment the next day—a period of more than eighteen hours.

As a rule, the pulmonary artery bifurcates just inside the pericardium, hence it is easy to slip a ligature around the left branch. Clamp A, illustrated in Figure 1, is then adjusted. Its right-angled base rests lightly against the artery, and the ligature is threaded into the clamp as shown in the illustration. Another ligature is then passed

around the whole pulmonary artery just above the bifurcation, thus allowing a sufficient length of the artery to permit insertion of the pulmonary cannula without impinging upon the pulmonic valves. In passing this ligature some sharp dissection is often necessary as the aorta and pulmonary artery are frequently bound firmly together. The pulmonary artery ligature is next threaded into a clamp similar to that controlling the left branch. This arrangement enables the operator, by the manipulation of a thumb screw, to compress the whole pulmonary artery, its left branch, or both, and, if he desires, to release the compression.

The pulmonic cannula<sup>11</sup> is then inserted into the main artery just below the angle formed as it bends posteriorly toward the hilus of the lungs. As a final step, a glass oncometer, covered with a very fine rubber dam, is slipped into place. A stitch, taken previously in the apex of the heart, is led through the oncometer tube and, with the aid of a needle, is passed through the rubber tube connected with the recording lever. The heart is thus held snugly in place within the bell of the oncometer. All of these adjustments are easily made after completing the operative procedure described and can be accomplished without the use of artificial respiration.

The tracheal cannula (Fig 2) is then connected through the arms *A* and *B* (*C* and *D* being shut off) with the inspiratory and expiratory Tissot valves. The arms *C* and *D*, the inflow and outflow lines, respectively, connect with the artificial respiration pump. Arm *E* is tied into the trachea. When artificial respiration is in use, *A* and *B* are, of course, closed. The expired air of the animal escapes through a T-tube into the room or may be collected and accurately measured in a delicately balanced spirometer. Thus, the volume of respired air is easily determined at any time during the experiment.

The systemic blood pressure is recorded from the femoral or from the carotid artery in the usual way. Both systemic and pulmonary cannulas are connected with manometers by means of rubber tubing filled with 8 per cent sodium citrate solution—the systemic cannula with a mercury manometer, the pulmonic cannula with a delicate membrane manometer. The respiratory rate is recorded by means of a pneumograph placed either on the upper abdomen or on the lower thorax of the animal.

Figure 3 illustrates the clamp (Clamp B) employed in producing graduated partial compression of the pulmonary artery. The bar *A-B* is passed beneath the artery resting lightly against its inferior surface,

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<sup>11</sup> Swift W. E. Haggart G. E. and Drinker C. K. A New Method for Measuring the Pressure in the Pulmonary Artery. *J. Exper. Med.* **36** 329 (Sept.) 1922.



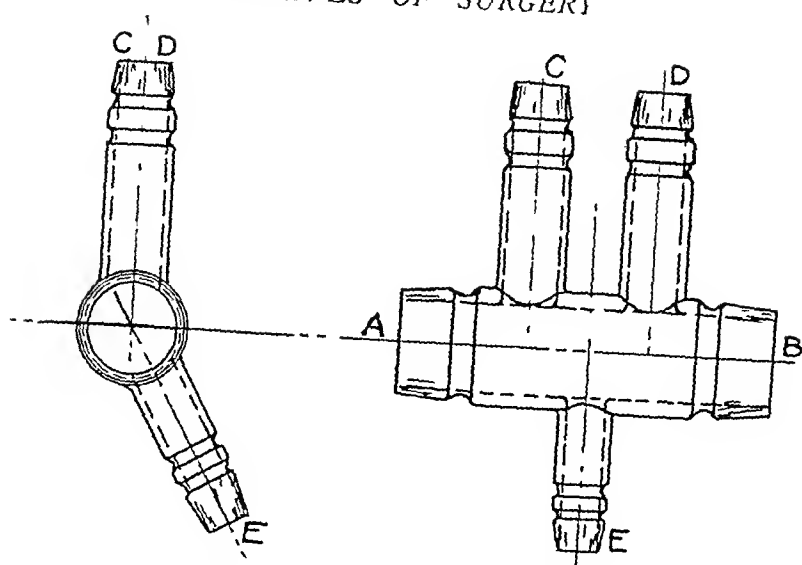


Fig 2—Tracheal cannula cross-section and anterior view

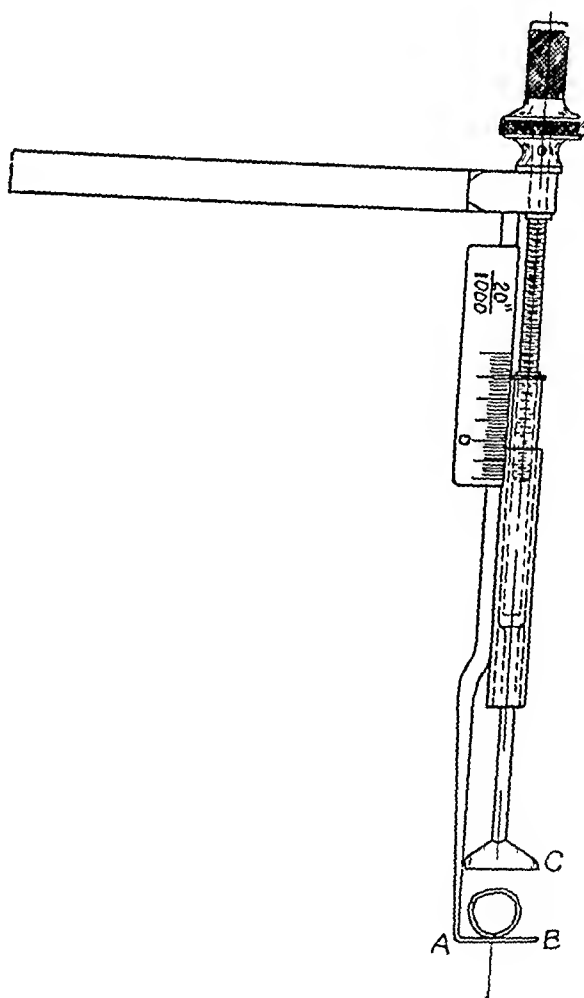


Fig 3—Clamp B, used for graduated partial compression of the pulmonary artery

the vessel being placed in the center to allow for lateral expansion in both directions. The plunger *C* is then screwed down until it just touches the superior wall of the artery. Readings on the scale (which is adjustable) give the external diameter of the artery and the zero from which the compression readings begin.

At the end of each experiment, the plunger was screwed down until the artery was occluded. The corresponding scale readings were then noted and interpreted in terms of a curve developed from a series of calculations made from an elastic rubber tube. In developing the curve the rubber tube was compressed gradually, and at various points inked impressions of its end were stamped on paper. This resulted in a series of diagrams showing change in shape and area of the tube during progressive compression. A measurement of these diagrams made it possible to compute the area of the opening during any degree of compression by the formula,  $O = \pi r^2 + 2rl$ , in which *O* is the area of the opening at the point of compression, *r*, the radius of the lateral curvatures of either side of the compressed tube, and *l*, the transverse distance across the artery from the end of one curved edge to the beginning of the other. The calculations so obtained have been plotted in terms of percentage, the degree of compression against the percentage decrease in radius.

#### EXPERIMENTS

The left pulmonary artery was completely occluded sixteen times in a series of thirteen cats, for periods varying from three to fifteen minutes (with one compression of seventy-two minutes). Records were made of the resulting changes in systemic and pulmonic blood pressures, in the cardiac output and in the rate and volume of respiration. These changes are presented in Table 1 and may be summarized thus:

*Blood Pressure in the Femoral Artery*—The average pressure before compression was 70.5 mm of mercury, the range being from 44 to 110 mm. The application of compression was without immediate effect on the pressure level. Subsequently, and usually within the first minute of the experiment, the pressure altered somewhat. In nine of the twelve cases recorded this alteration was a rise, but in no instance did it exceed a 14.2 per cent variation.

*Blood Pressure in the Pulmonary Artery*—In the fifteen cases in which this measurement was recorded, the average pressure preceding compression was 14 mm of mercury, the range being from 9 to 23 mm. In all instances except one, in which no change occurred, there was an abrupt rise in pressure when compression was applied, but in only three cases was this rise greater than 33 per cent (50, 83.3 and 100

SSURE IN THE SYSTEMIC AND  
P. SPIRATION

Occlusion of the Left Heart, and on the Rate and the Pulmonary Arteries on the Heart, and on the Rate and the Pulmonary Arteries		Respiration in Relation to Compression		Rate per Min	
Heart Findings in Relation to Compression		Tidal Air (in 3 Min), Cc		Before	During
Biventricular					

Experiment	Duration of Occlusion, Min	Femoral Blood Pressure in Relation to Compression, Mm			Pulmonary Blood Pressure in Relation to Compression, Mm			Dilatation During	Before		During	Before	Readings
		Before	During	After	Before	During	After						
1	3												
2A	6	101	110 104	101	19	24	24	Slight, until compression release	680	518	734	1,193	567
2B	6	108	108 105	108	23	26-24	26-24	Slight prolonged	210		1,910	2,075	1,938
3	72	62	62 (30')†		14	15 14 (30')	15 14 (30')	Slight temporary	900	100 240, 210 810 (30')	3,990	2,130	1 9 0
4A	3	50	51	50	12	14 12	24	None (30')	720	720	2,348	1,832	
5	3	71	66-68	73	18	20 19	26-24	Slight, temporary	435	360	1,467	1,932	
6	2	60	64 66		18	15-12	15 14 (30')	None	740	340	1,260	1,701	
8	11	62	64		12	16-15	14 12	None	371	465			
9	14	44	43-45		17	19 15	20 19	None	468	691			
10A	4	50	52	74	12	22 17	15-12	None, temporary	562	546	2,022	2,140	2 300
10B	5½	66	62	108	12	14	16-15	Slight, permanent	672	672	1,900	2,030	
11	5	110	113 110		12	18	22 17	Severe	846	825			
12A	2				12	16	14	None	826				
13 (ether)					12	18	18	Slight for 10 seconds					17
After vaginal section	3				14			None				2,990	
4B	5				11			None				1 318	
12B													

whenever possible, but in light of compression it was not released until further experimentation rendered readings of compression it which observation was made of compression it which observation

\* This measurement taken at intervals of ten minutes indicates the permanent effect of compression on the heart and on the pulmonary artery, following permanent occlusion of the systemic arteries.

[illegible]

Experiment	Duration of Compression See	Femoral Blood Pressure in Relation to Compression Mm			Pulmonary Blood Pressure in Relation to Compression, Mm			During	After	Recovery	No recovery	No recovery	Death	If the decreased oxygen sufficient clamp was loosened
		Before	During	After	Before	During	After							
9	12	52	16	61	15	37	11	680	Partial recovery				437-648	
10	4	11	19	32	14	31	14	814	Partial recovery				690-100	
11	2	46	17	22	12	11	13	766	No recovery				369-237	

20	17	22
40	46	
7		

Completion was 100% complete in this instance

per cent, respectively) In the remaining twelve records the average change was only 16.9 per cent, or 2.7 mm The average for the fifteen determinations was 29 per cent During compression the tendency seemed to be toward a return to the control pressure, especially in those cases in which the shift had been least extensive Compression release was usually without marked results in decreasing the pulmonary arterial pressure

*Cardiac Dilatation*—In nine of the sixteen instances, the oncometer record showed no cardiac dilatation whatever at any stage of the compression In six of the remaining seven a very slight dilatation occurred immediately upon the application of compression, but in all except two of these—in which dilatation lasted until compression was removed—the heart returned to its control size (in from ten seconds to two and one-half minutes) before the pulmonary block was released The only case of severe permanent dilatation occurred in a heart which had been previously weakened by a temporary occlusion of the entire pulmonary artery In this instance compression release did not cause the heart to return to its normal size

*Cardiac Minute Volume*—In fifteen instances, the biventricular output before compression ranged from 210 to 900 c c, the average being 628 c c per minute delivered in 168 strokes of approximately 4 c c each In six of the experiments, no change whatever took place during compression In another seven, there was a permanent decrease in volume that averaged 11.6 per cent and in no case exceeded 23.8 per cent This decrease was accomplished more often by a diminished output for each beat than by a diminution of rate, though the latter sometimes occurred In one experiment, there was a minute volume increase of 5.8 per cent In another (Experiment 2 B, Table 1), we obtained a temporary decrease in minute volume accompanying some degree of cardiac dilatation, with a return to normal after a compensatory period of increased output

*Tidal Air*—With the exception of two unusual cases in which the figures of 734 and 5990 were obtained, the three-minute volume of tidal air before compression, with vagi intact, ranged from 1,260 to 2,348 c c The average in the ten cases without vagal section was 2,137 c c In every instance, collections taken during the period of compression showed an increased tidal air This increase varied from 7.9 to 62.6 per cent, was below 12 per cent three times, above 35 per cent once and averaged 25.7 per cent Collections made from one to three minutes after compression release showed a return toward the control figures in every case In twelve of the fourteen cases in which the respiratory rate was determined, the average rate before compression was 33.6 per minute, and after compression 35.4 per minute

—an increase of 54 per cent, which seems insufficient to account for the increased tidal air without premising an accompanying increase in respiratory depth

Table 2 illustrates the striking reaction secured by adding a brief but almost complete occlusion of the pulmonary artery to permanent compression of its left branch. The results vary with the severity of the compression applied, but it will be noticed that while the femoral blood pressure falls sharply to about one third of the control level—an average variation of 63 per cent—the pulmonic pressure rises from 121 to 267 per cent, that the heart dilates severely and usually permanently, its minute volume decreasing from 15 to 66 per cent, and that respiration becomes irregular and stops. If the application is brief enough, the systemic pressure will again rise, respiration will recommence, and the animal will live for some time.

Figures 4 and 5 record typical results secured by compression of (a) the left pulmonary artery and (b) the entire pulmonary artery. Both of these tracings are taken from Experiment 9, the details of which are given herewith.

#### REPORT OF EXPERIMENT

EXPERIMENT 9—Oct 23, 1922, a cat weight 27 kg at 9 a m, was given 675 gm of ethyl carbamate by stomach tube. At 11 05 a m, the operation was finished with chest tight and with ligatures placed around the left pulmonary artery and around the pulmonary artery just mesial to its bifurcation. The ligature clamps and the cardiometer were adjusted, a cannula was inserted into the pulmonary artery, and arrangements made for recording the rate of respiration and femoral blood pressure. At 11 41 a m, a control collection showed the tidal air to be 1,260 c c in three minutes.

At 11 50 a m, the left pulmonary artery clamp was tightened and the entire blood supply of the left lung thereby suddenly and entirely obstructed.

The result is illustrated in Figure 4. Tracing 1 is the oncometer cord, and reveals alteration neither in the size, rate nor stroke delivery of the heart. Tracing 2 represents the abdominal respiration and shows an increase in rate following compression of from 30 to 35 per minute. Tracing 3 shows a femoral blood pressure of 62 mm of mercury, which rises after compression to a sustained level of 64 mm. Tracing 4 is the pulmonary blood pressure, and, in this instance, presents on compression a mean pressure rise of from 17 to 19 mm of mercury. Marks on the base line of this tracing signal events in the experiment. Tracing 5 is the time clock marking one-second intervals.

An air collection made at this juncture gave a three-minute total of 1,701 c c, an increase over the control of 34.5 per cent.

At 11 56 a m, after a five-minute occlusion of the left pulmonary artery, the ligature about the pulmonary artery was tightened. The occlusion, which was almost complete, was loosened at the end of thirty-one seconds.

The results of the latter procedure are illustrated in Figure 5. The tracing numbers here have the same indications as those in Figure 1. Mark 1 shows the application of pressure, Mark 2, its removal. It will be noticed that

(a) The heart dilated sharply and the stroke output decreased markedly (689 to 437 c c) One minute after compression was released, the dilatation was becoming less, and the minute volume was compensatorily great (792 c c) In another minute the cardiac size was as in the control, and the minute volume had returned to normal (648 c c)

(b) Respiration became irregular, ceased entirely, and did not begin again until compression had been removed for thirty-seven seconds

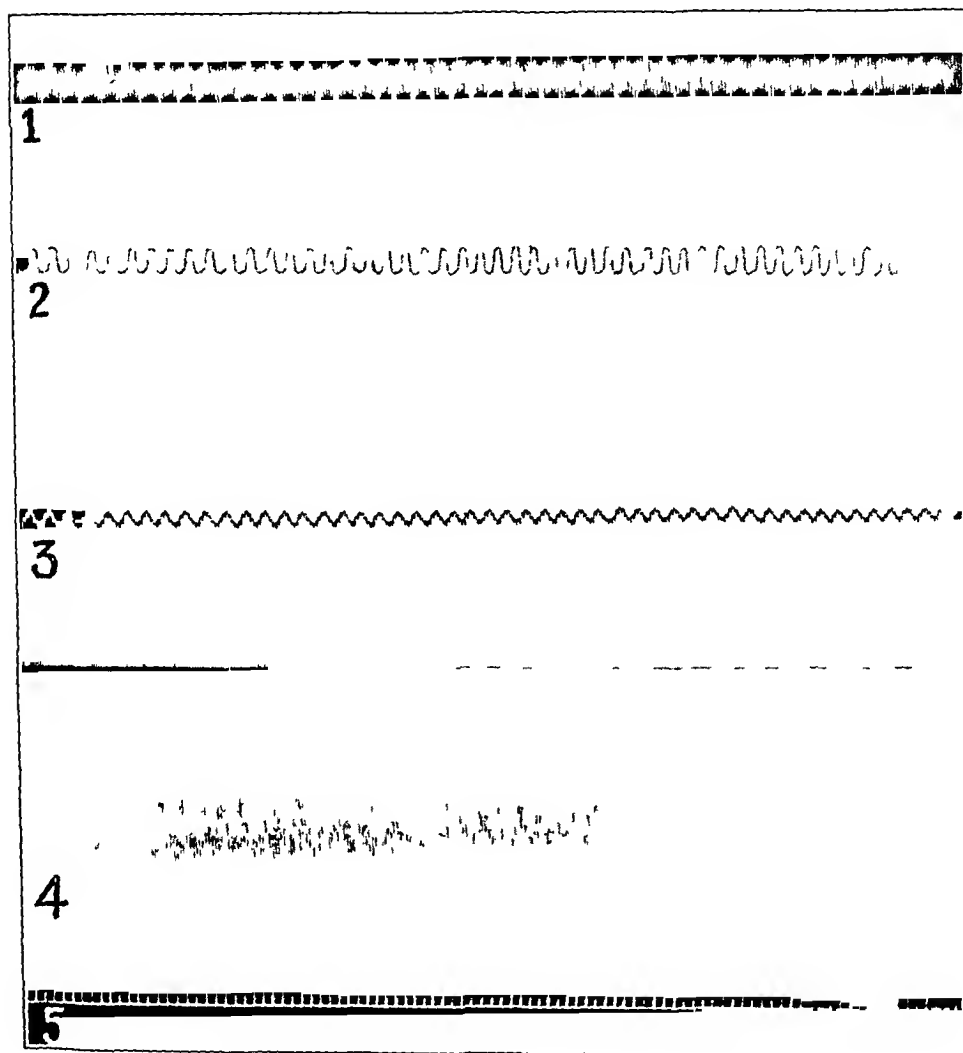


Fig 4—Record showing absence of any reaction following compression of the left pulmonary artery (Experiment 9) Tracing 1, oncometer record of heart volume, Tracing 2 respiration, Tracing 3, systemic blood pressure, Tracing 4 pulmonary blood pressure Tracing 5, one-second intervals Mark 1 on the base line of Tracing 4 signals the application of compression

(c) Very shortly after the ligature was tightened the femoral blood pressure fell quite abruptly from 52 to 16 mm of mercury At this level it continued until compression was released when it rose to its former level in approximately seventy seconds



Tracing 1 oncometer record of  
Tracing 5, oncometer record of  
Tracing 4 pulmonary blood pressure  
Tracing 3 systemic blood pressure  
Tracing 2 respiration

Fig 5—Record showing effect of total compression of the pulmonary artery (Experiment 9) Tracing 1 oncometer record of heart volume Tracing 2 respiration Tracing 3 systemic blood pressure Tracing 4 signal application and release of compression second intervals. Marks on the base line of Tracing 4

(d) The pulmonary blood pressure rose very suddenly from 15 to 37 mm of mercury, the up-stroke being limited by the interference of the systemic base line. Before compression was removed it had fallen to 18 mm of mercury, owing probably to failure of the right heart as a result of coronary anemia. After removal it fell to 11, and ninety seconds later it again rose to 28 mm of mercury, where it remained.

At 12 03 p m, a collection showed that the three-minute tidal air had increased to 2,103 c c. At 12 04, compression was removed from the left pulmonary artery. At 12 08, the tidal air had fallen to 1,913 c c. At 12 09 the animal was bled to death from the femoral and pulmonary arteries. Examination showed the ligatures to be in the positions indicated.

In one experiment in this series (Experiment 3), forty-five minutes after pressure was applied the heart had not dilated, the pulmonary arterial pressure

TABLE 3—EFFECT UPON THE SYSTEMIC AND THE PULMONIC ARTERIAL PRESSURE OF GRADUATED PARTIAL COMPRESSION OF THE PULMONARY ARTERY

	Systemic Blood Pressure, Mm Hg	Pulmonic Blood Pressure, Mm Hg	Cardiac Size	Biven- tricular Minute Volume, C c	Respiratory Rate per Minute
Experiment 19					
Without compression	62	12	Normal	504	30
At 60% compression	58	13	Slight dilata- tion	504	30
At 62-66% compression	18	14	Sharp dilata- tion	77	30
Experiment 20					
Without compression	60	17	Normal	858	24
At 60% compression	60	19	Slight dilata- tion	780	32
At 62-66% compression	12	20	Sharp dilata- tion	252	40 (irregular and stopped)
Experiment 21					
Without compression	54	17	Normal	806	30
At 60% compression	44	17	Dilatation	672	30
At 62-66% compression	12	34	Dilatation	101	Irregular and stopped
Experiment 26					
Without compression	48	10			48
At 60% compression	38	11			48
At 62-66% compression	12	12			Irregular and stopped

remained at its control level, the femoral pressure had only fallen 12 per cent, and though the cardiac output had decreased 30 per cent the tidal air was but 10 per cent less than the control. Shortly after this, the lung ventilation began to decrease quite rapidly. With this change the femoral pressure fell, the heart dilated, and in an hour and twelve minutes the cat died.

These and similar experiments show not only that there are no immediate results of vital consequence from occlusion of the left pulmonary artery but also that secondary changes are extremely slow in making their appearance.

Our work with graduated compression of the pulmonary artery in four cases is summarized in Table 3, and Figure 6 gives a tracing from Experiment 19. Mark 2 on the record is the point where occlusion reached 60 per cent and mark 3, where it reached 65 per cent. In



these four experiments the pressure levels were unchanged at 55 per cent, a slight reaction occurred at 60 per cent, and the end-point, marking the rapid onset of death, occurred on the average at 64 per cent—the range being from 62 to 66 per cent. In the remaining three cases this end-point occurred with this degree of occlusion 64 per cent, 55 per cent and 52 per cent. Figure 7 records the strik-

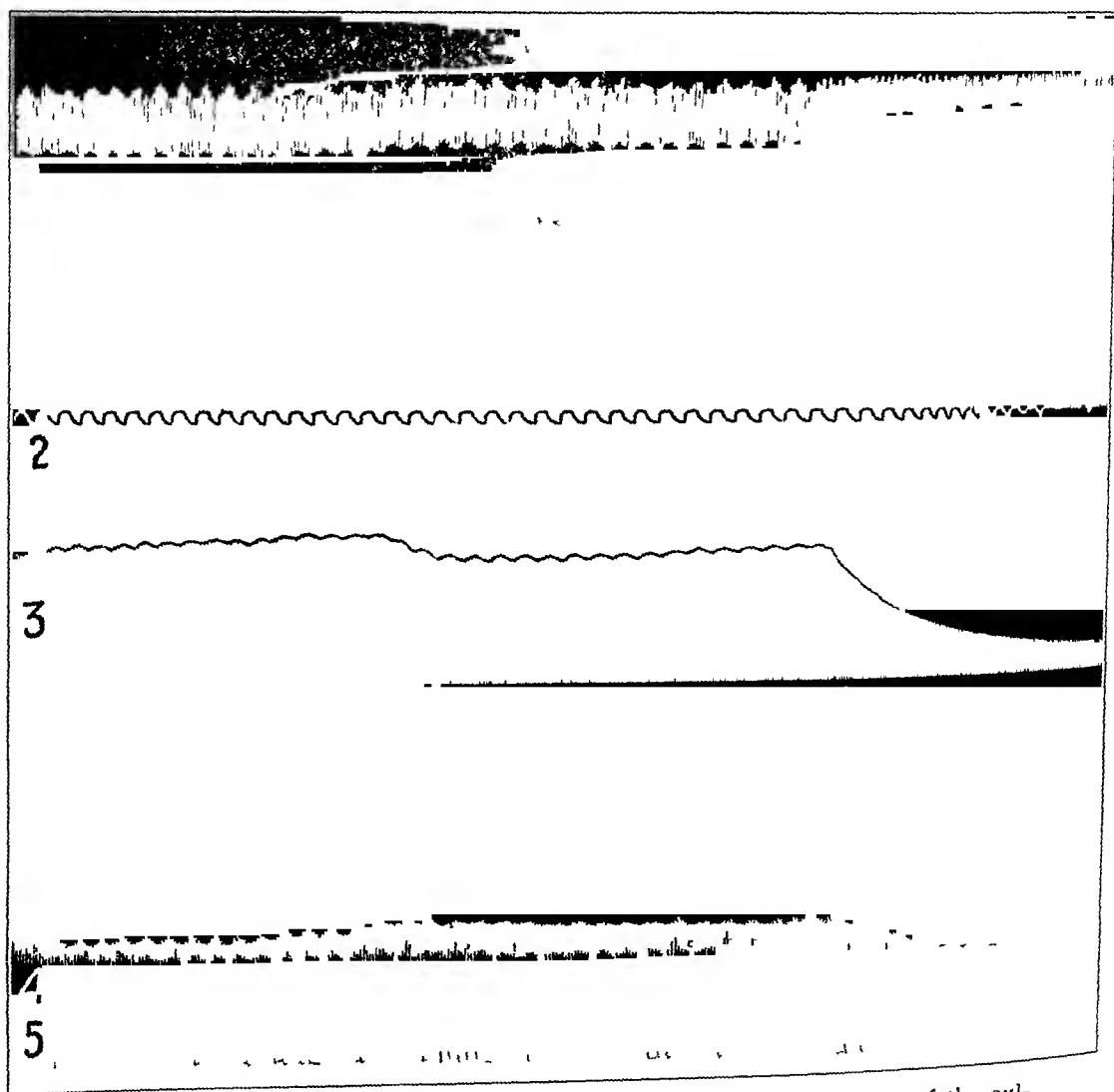


Fig 6—Record showing effect of graduated partial compression of the pulmonary artery (Experiment 19). Tracing 1, oncometer record of heart volume, Tracing 2, respiration, Tracing 3, systemic blood pressure, Tracing 4, pulmonic blood pressure, Tracing 5, one-second intervals. Mark 2 on the base line of Tracing 4 signals compression of the artery amounting to 60 per cent occlusion. Mark 3 signals 65 per cent occlusion—the point of heart failure in this animal.

ing results obtained in Experiment 26. The pulmonary artery was occluded three times with exactly the same amount of compression applied in exactly the same manner, and in each instance failure

occurred when 55 per cent of the artery was shut off. Following release of the clamp after the first and second compressions, the heart diminished in size, and the systemic blood pressure again mounted to a level slightly below the control. At this point the procedure was again repeated, but following release of the clamp for the third time the respiration failed to begin, the heart remained dilated, and the animal died.<sup>12</sup>

#### COMMENT

These experiments were undertaken to determine the reactions of the greater and lesser circulation and of the respiration to partial and to complete pulmonary arterial block, a condition, as here presented, quite analogous to pulmonary embolism in man. The technic described has provided experimental conditions more closely approaching those existing in the normal animal than it has heretofore been possible to secure. In consequence, we believe the results may be regarded as indicative of the circulatory reaction to be expected in a case of pulmonary embolism.

The experiments fall into three groups: (a) those in which the left pulmonary artery alone was compressed, (b) those in which the whole artery was suddenly occluded, and (c) those in which the whole artery was obstructed by graduated partial occlusion. The latter work was done with the idea of ascertaining to what extent the total pulmonary circulation could be encroached upon before signs of general cardiac and systemic failure became evident.

(a) *Results of Left Pulmonary Artery Compression*—In these experiments certain reactions, or, better, lack of reactions, were observed. To begin with, dilatation as measured by the oncometer occurred in the heart itself in only seven out of sixteen cases. In four of these it was very slight, and recovery occurred during the compression. In two it was also slight, but recovery did not take place until the block was removed. In the remaining case the dilatation was sharply marked, and without recovery. In this instance, however, the entire artery had been compressed and released early in the experiment, and the heart was undoubtedly damaged. The remaining experiments revealed no dilatation of the heart whatever. In six out of fifteen cases, moreover, there was no alteration during compression of the minute volume output of the heart. Of the other nine experiments, all except one show only a slight decrease (Table 1). So far, therefore, as the entire removal of one half of the pulmonary circulation is concerned, the effect upon the heart is essentially nil. This observa-

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<sup>12</sup> In this experiment, between Mark 7, when conditions in the animal were not seriously abnormal, and Mark 8, when cardiac failure occurred, the lumen of the pulmonary artery was narrowed by 0.036 sq. cm.

tion is in entire accord with that of Underhill,<sup>6</sup> who sums up his experience thus "The healthy heart, therefore, can accommodate itself without difficulty to sending the same volume of blood through one lung only in a given time, as it previously sent through both."

As to the effect upon the pulmonary arterial pressure (Table 1), it will be observed that in every instance except one the pressure rose, usually rather abruptly, the degree of the rise varying in height, according to experimental conditions, but averaging about 29 per cent. During compression the tendency was toward a return to the control level. Thus, the rise in pressure in the pulmonary artery following an *embolus* of its left branch was quite distinct, and yet not sufficient to embarrass the heart action. It is of interest to contrast these findings with those obtained by compression of the pulmonary veins. In the latter experiments, the pulmonary arterial pressure rises sharply and to a height which frequently is twice that recorded when the left artery is compressed. Results of experiments of this type will be published later.

The effect on systemic blood pressure caused by sudden occlusion of the left pulmonary artery is shown in Table 1. In one out of twelve cases compression produced no change. In nine of the experiments there was an average rise of 4.2 mm., while in the remaining two an average fall of 5.5 mm. occurred. It is clear, therefore, that halving the pulmonary circuit has little or no effect upon the general systemic circulation.

The respiration, under this procedure, shows a constant change. The number of inspirations usually increases to a slight extent and their depth is greater (direct observation). The total ventilation shows a definite and, at times, a marked increase, the average rise being 25.7 per cent.

The cause of this hyperpnea raises an interesting point. It is doubtless due in part to the fact that one lung alone must now aerate the blood. Dunn<sup>7</sup> is of the opinion that this hyperpnea is probably "brought about by reflex action, initiated by stimulation of sensory nerve endings in the lungs." He cites experiments in which, with the vagi cut, extensive starch embolism was produced in goats. The respiratory rate, however, remained quite unaltered.

To investigate this point, we carried out experiments in which the left pulmonary artery was clamped before and after vagal section. The resultant circulatory changes were essentially those already described, but there was a decided difference in the effect upon the ventilation. After cutting both nerves, in one instance a previous increase of 25 per cent was reduced to 9 per cent, while in another experiment an increase of 20 per cent was replaced by a reduction in ventilation of 30 per cent.

These findings confirm those of Dunn<sup>7</sup> and make additionally justifiable the assumption that the vagus nerves are evidently an important link in causing the hyperpnea following pulmonary embolism. It is also worth while to comment, in this connection, on the definite evidence presented of a "very considerable reserve of vascular area in the lungs." In our experiments the function of one entire lung is wiped out, and yet the general circulation is well maintained—at least, as Dunn adds, "for the resting animal."

In summary, we may say that an animal under ethyl carbamate or ether anesthesia can bear a sudden stoppage of blood flow in the left pulmonary artery—a condition analogous to that of embolism of the vessel in man—without any sustained effect other than some increase in the respiratory ventilation and a rise of approximately 29 per cent in pulmonary arterial pressure.

(b) *Results of Total Pulmonary Artery Compression*—In this group of experiments in which the entire pulmonary circulation was suddenly blocked off, very marked changes in the respiration and circulation were observed (Table 2). When the pulmonary circulation is entirely blocked, there results an immediate dilatation of the heart and a rapid diminution of its output. The pulmonary arterial pressure rises sharply—on the average between 121 and 267 per cent—and then falls. This occurs before the clamp is removed, presumably because of right ventricular failure dependent on insufficient coronary flow which results from a lowered systemic pressure. The systemic blood pressure falls rapidly and, unless the compression is immediately removed, continues to drop until it reaches zero.

It is worth while pointing out that, following this compression, the fall in systemic blood pressure, as indicated by the sloping curve obtained (Fig. 5), is not abrupt but is, on the whole, a rather gradual decline. This occurrence is probably best explained as being due to the gradual feeding of the blood present in the lungs at the time of the arterial obstruction to the left heart through the mechanical act of respiration. The final failure of systemic pressure is thus delayed in proportion to the volume of blood present in the lungs.

The effect of compression of the pulmonary artery upon respiration is immediately noted. The breathing becomes irregular, soon stopping altogether, and usually fails to begin again even when the compression is promptly released. Total sudden occlusion of the lesser circulation even when present only a few seconds, evidently, therefore, entails such severe results that the animal is seldom able to recover. This fact still holds even though, with the compression released, artificial respiration is begun and epinephrin given into the left side of the heart.

Clinically these facts are borne out by the findings of Petré<sup>13</sup> who, from an analysis of a series of patients dying of pulmonary embolism, is of the opinion that following embolic block of one pulmonary artery death does not always supervene, whereas in those persons suffering from even temporary occlusion of the whole artery, the result is invariably fatal.

In brief, we believe the sequence of events leading to death from pulmonary embolism to be a rise of pressure in the pulmonary artery, dilatation of the right ventricle and a fall in systemic blood pressure, resulting in malnourishment and failure of the right heart. The respiratory center fails following the drop in systemic blood pressure.

(c) *Results of Graduated Partial Compression of the Pulmonary Artery*—Up to this point the observations reported are those made following occlusion, first of one-half and then of the whole pulmonary artery. To complete the study of quantitative occlusion of this artery, it was our aim to determine how much of it could be occluded before there appeared any signs of cardiac failure, fall in blood pressure, etc.—in other words, to discover to what degree the whole pulmonary circuit might be blocked off before symptoms developed which were at all comparable to those resulting from complete embolism of the artery. To obtain such data, it was first necessary to devise means by which it would be possible to narrow the lumen gradually and, the diameter of the artery being known, to measure accurately at any moment the degree of the occlusion. This would enable us to determine the exact amount of compression applied when the recording manometers first gave evidence of an embolic effect. Clamp B, illustrated in Figure 3, fulfilled these requirements.

The operative procedure was the same as that previously described, except that in the majority of the cases a ligature tied around the left pulmonary artery was substituted for Clamp A. Experimental results with the left branch patent were essentially the same as those noted below. When Clamp B was in position, the plunger was gradually screwed down, starting with a distance equal to four scale divisions, and then progressively increasing the compression, one unit at a time—a compression of one-fiftieth of an inch. Following each increment of compression, sufficient time was always allowed to make sure that there was no delayed after-effect.

In each experiment, this gradual narrowing of the pulmonary arterial stream continued without obvious effect until a large part of the total pulmonary artery was closed. At this juncture there was a definite endpoint. Indeed, so sharply was it defined that further clamp

13 Petren, G. Studien über obturierende Lungenembolie als postoperative Todesurache, Beitr. z. klin. Chir. 84 606 (May) 1913.

closure of one-fiftieth of an inch precipitated an immediate reaction. When this endpoint was reached the heart dilated sharply, with a corresponding decrease in minute volume output, the systemic pressure fell rapidly at first and then more gradually, while the pulmonic pressure rose abruptly. Respirations became irregular and soon ceased entirely. The percentage occlusion of the artery which produced such a reaction in four of these experiments is strikingly similar—66, 65, 64, and 62 per cent, or an average of 64 per cent.

In the remaining cases the reaction occurred at 55 and 52 per cent occlusion. The first of these is of particular importance and is illustrated in Figure 7. The fact that exactly the same degree of occlusion could be provided, three successive times, and in each instance would bring about an abrupt and, if unrelieved, fatal reaction in the animal is of great interest and is the subject of further investigation in this laboratory. Many factors must take part in inducing this type of cardiac failure. As the pulmonary artery is narrowed, the amount of blood reaching the left ventricle finally becomes less and less. Systemic blood pressure falls and with it the pressure in the coronary vessels. At the same time the heart dilates, the muscle fibers are placed under increased tension and probably require additional oxygen for adequate contraction, instead of the reduced amount with which they are provided, owing to the lowered systemic blood pressure. Furthermore, it seems probable that as dilatation advances the cardiac capillaries may suffer mechanical closure or reduction in lumina so that a further factor is added to the vicious cycle which arterial obstruction has initiated.

*Postmortem Findings*—In those experiments in which occlusion of the left pulmonary artery was maintained, a distinct, though not marked, difference in the appearance of the two lungs was noted. The left lung, from which the blood was shut off, was definitely paler than the right, the latter presenting a faint pink blush, quite noticeable when contrasted with normal lungs. This was particularly well demonstrated in the experiment on the animal in which the clamp was maintained in place for more than an hour. In these findings we disagree with Underhill, who notes that the blocked lung, chest closed, is always more congested, while in an open chest experiment the opposite is the case.

It is interesting to note that when the pulmonary artery clamp was removed, following a period of compression, and blood was again allowed to flow through the lung, postmortem examinations showed the lung congested, a marked generalized reddish color—at times even a brilliant salmon hue—being visible. The lung felt soggy, and a thin bloody fluid oozed freely from the cut surface. On section, the alveoli

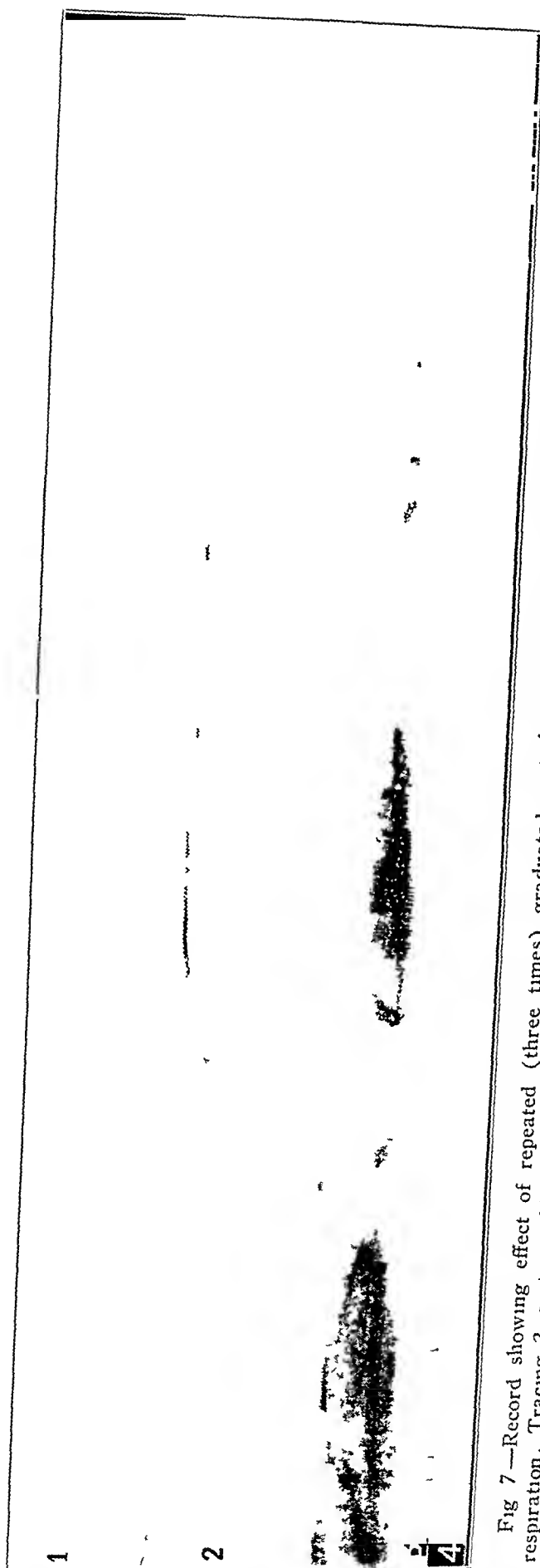


Fig 7 —Record showing effect of repeated (three times) graduated partial compression of pulmonary artery (Experiment 26) Tracing 1, respiration, Tracing 2, systemic blood pressure, Tracing 3, pulmonary blood pressure, Tracing 4, one-second intervals The marks on the base line of Tracing 3 signal application of units of compression, Mark 8 in each series indicating 55 per cent, occlusion—the point of heart failure in this animal

were engorged with red corpuscles. There was some edema. This change we consider due to capillary damage, possibly resulting from a local alkalosis due to deprivation of carbon dioxide.

#### CONCLUSIONS

1 In the method described, it is possible, in the normally breathing animal to produce partial or complete block of the pulmonary artery, the condition as here brought about being analogous to pulmonary embolism in man.

2 Clamping the left branch of the pulmonary artery causes an immediate rise in pulmonary pressure, averaging about 29 per cent, and such a procedure causes no significant change in the general systemic pressure nor any significant variation in size of the heart, heart rate or heart output. Ventilation, as measured by a spirometer, is, however, increased approximately 25 per cent, a moderate hyperpnea resulting.

3 Following total pulmonary occlusion a severe and immediate reaction sets in. The heart dilates quickly and to a marked degree, the minute volume output becoming materially less. The pulmonary pressure rises sharply—121 to 267 per cent—and then gradually falls toward zero. The systemic pressure begins to fall immediately and does not recover, while respirations become irregular and shortly thereafter cease altogether.

4 Until from 52 to 66 per cent of the pulmonary circulation is cut off there is no significant variation in the general circulatory condition of the animal. The point at which failure occurs is sharply defined, since beyond this endpoint a circulatory collapse is precipitated by a minute increase in the arterial obstruction, but if this is not applied no untoward change results.



# STUDIES ON THE CALCIFICATION OF CALLUS\*

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In a previously published article, I<sup>1</sup> reported the results of experiments which I had performed to determine the effect of variations in the blood phosphorus on the rate of calcification of callus in fractures. These experiments were made on the basis of reactions in vitro and with recent work on rickets as a background, and they were entirely negative. Continued interesting reports on experimental rickets have stimulated the present attempt to accelerate the calcification of fracture callus through the application of the factors that will influence the calcification of bone in that condition.

Workers on the vitamins lay stress on the fact that no good is to be expected from any superabundance of these substances in the dietary intake. Deficiency alone is of significance. In the presence of conditions brought on by deficiency, an addition to the diet of the particular vitamin concerned will result in a return to normal. The fact that the ingestion of cod liver oil under such circumstances will result in a rapid deposition of calcium in calcium-deficient bones<sup>2</sup> suggests the possibility that this power to influence the deposit of calcium might extend beyond the abnormal rickety state, in spite of the general rule mentioned above. It was hoped that the effect might be the same in a condition in which there is equally a functional demand for calcium, namely, in the presence of a soft fracture callus.

It has been shown that, in animals fed on diets deficient in fat-soluble A, the deficiency state could be prevented from developing by

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1 Lehman, E P. Studies in Inorganic Blood Phosphate, *J Biol Chem* **48** 293 (Oct) 1921

2 Shipley, P G, Park, E A, McCollum, E V, Simmonds N, and Parsons, H T. Studies on Experimental Rickets, II. The Effect of Cod Liver Oil Administered to Rats with Experimental Rickets, *J Biol Chem* **45** 343 (Jan) 1921. McCollum, E V, Simmonds, N, Becker, J E, and Shipley, P G. Studies on Experimental Rickets, XXI. An Experimental Demonstration of the Existence of a Vitamin Which Promotes Calcium Deposition, *Bull Johns Hopkins Hosp* **33** 229 (June) 1922

exposure to direct sunlight<sup>3</sup> In the present series of experiments, the effect of sunlight was also tested in the healing of fractures in the normal rat

In a third type of experiment, the effect on fracture callus of each of these two influences in animals rendered somewhat rickety was also studied Diet 3143 of McCollum and his associates<sup>4</sup> was chosen This diet will produce marked rickets in young rats in from thirty-five to forty days and will not produce xerophthalmia It contains "proteins of good quality (about 33 per cent) and about twice the calcium necessary for optimal growth and nutrition It is, however, low in fat-soluble A and below the optimum in its content of phosphorus"<sup>5</sup> Sunlight and cod liver oil, to the amount of 2 per cent of the weight of the diet, will each protect against the development of rickets The study of the healing of fractures in rickets was not intended, it was hoped only that, if the effect of these influences on callus was not demonstrable in normal rats, they might be shown to affect callus favorably if there was established a tendency toward the withdrawal of calcium from the bones For this reason, the preliminary period of feeding was limited to twenty-four days, and the animals were all killed at thirty-eight days Such animals did not show marked anatomic changes at death, but they were distinctly below the normal in weight, and their bone repair, as will appear, was less strong Unfortunately, the material for microscopic study of the epiphyses and callus was lost

#### TECHNIC

The white rat was employed because it is the animal for which the foregoing facts have been standardized Each experiment was conducted with a single litter, divided into control and experimental animals They were fed on the standard laboratory diet of corn, carrots, meat and dog biscuit, unless otherwise stated The left humerus was used for experimental fracture and the right for control

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3 Hess, A F, and Unger L J The Cure of Infantile Rickets by Sunlight, *J A M A* **77** 39 (July 2) 1921 Hess A F, Unger L J, and Pappenheimer, A M Experimental Rickets in Rats, III The Prevention of Rickets in Rats by Exposure to Sunlight, *J Biol Chem* **50** 77 (Jan) 1922 Park, E A, Powers, G F Shipley, P G McCollum E V, and Simmonds, N Studies on Experimental Rickets, XIV The Prevention of the Development of Rickets in Rats by Sunlight, *J A M A* **78** 159 (Jan 21) 1922 Clark, J H The Physiological Action of Light, *Physiol Rev* **2** 277 (April) 1922

4 McCollum, E V Simmonds N Shipley P G and Park, E A Studies on Experimental Rickets, VIII The Production of Rickets by Diets Low in Phosphorus and Fat-Soluble A, *J Biol Chem* **47** 507 (Aug) 1921

5 McCollum, E V, Simmonds, N, Shipley, P G, and Park, E A Studies on Experimental Rickets, XV The Effect of Starvation on the Healing of Rickets *Bull Johns Hopkins Hosp* **33** 31 (Jan) 1922

The method of studying calcification by the roentgen ray is not subject to even approximately accurate quantitative interpretation. For that reason, a method of measuring the breaking and bending strength of the bones was employed. It is assumed in this method that the rigidity and strength of the callus is proportional to the calcium deposited in the cellular matrix. The apparatus illustrated in Figure 1, adapted from that used by Allison and Brooks,<sup>6</sup> was employed. The bone to be studied was placed in the grooves (*C*) of the side bars (*B*), within the yoke (*D*). The bone was accurately adjusted in exactly the

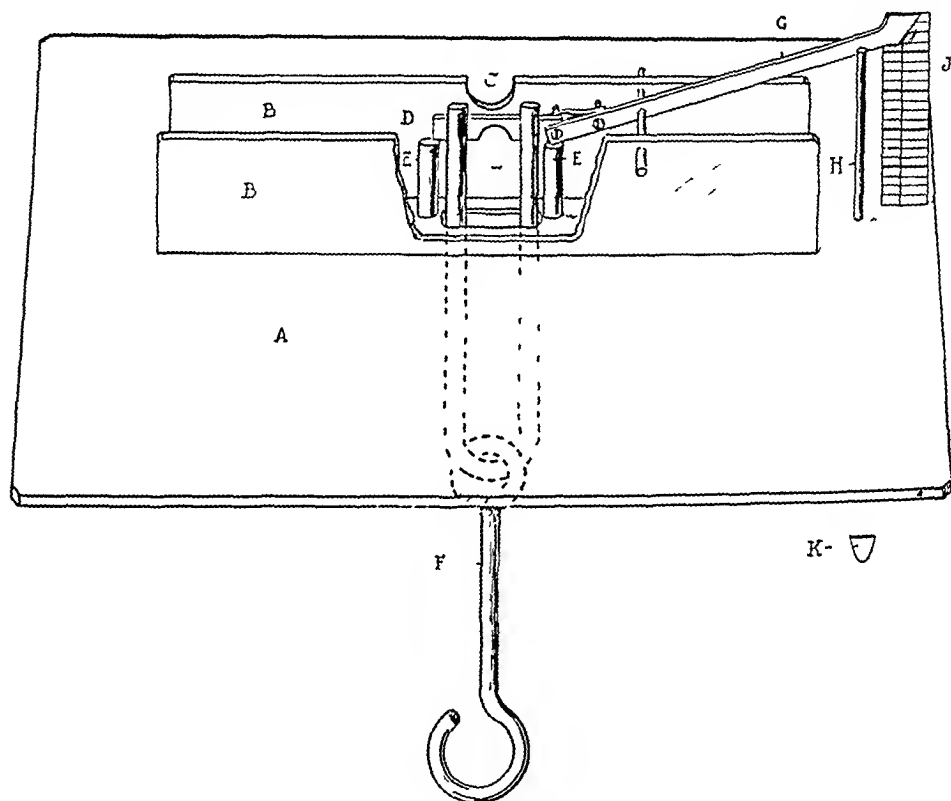


Fig 1—Apparatus for measuring bending and breaking strength of normal and fractured bones. *A*, base plate with orifice for yoke, *B, B*, side bars, *C*, groove for bone (a corresponding groove exists on the side bar broken away to show mechanism), *D*, yoke, with groove to fit over bone, *E, E*, stop posts, *F*, hook for sand bucket, *G*, bend-recording lever (ratio of 1:4), *H*, guide pin for lever, *J*, scale, *K*, cross-section of yoke at *L* to show edge where weight is applied to bone, rounded to prevent cutting of callus.

same relation to the side bars and the yoke in each instance. Sand was then added slowly to a light bucket, suspended from the hook (*F*), until breaking occurred. Bending was indicated by movement of the lever (*G*) on the dial (*J*) in a ratio of 4 to 1. The amount of weight necessary to bend or break was recorded by weighing the sand bucket.

<sup>6</sup> Allison, Nathaniel, and Brooks, Barney. Bone Atrophy, Surg., Gynec & Obst. **33** 250 (Sept.) 1921.

A series of twenty-six rats was employed in working out the details and accuracy of this technic. These preliminary experiments demonstrated that the method of placing the bone in the breaking machine is all-important. As can be seen by the sketches, the humerus of the rat is marked by a prominent ridge, which extends from the head, about halfway down the bone. In the control bones from each rat, the yoke was centered exactly at the base of this spur and the latter was made to lie in the horizontal plane. When so placed, results were sufficiently uniform to lie within biologic limits. At the conclusion of the experiments, three normal rats were studied as a final check on the method. In each of these, the breaking strengths of both humeri were measured. The results are shown in Table 1. Breaking of the normal bones always occurred sharply, without preliminary bending.

The problem of obtaining uniformity in measuring the strength of the callus of healing bone proved more difficult. Fortunately, it was

TABLE 1—BREAKING STRENGTHS OF RIGHT AND LEFT HUMERUS IN NORMAL RATS

Rat	Right, Gm	Left Gm	Percentage of Difference
1	1 920	2,080	8
2	2 300	2,190	5
3	4 080	3 800	7

found that by practice the bones can be broken at the same point *in vivo* in the vast majority of attempts. The rats were anesthetized with ether and the bones snapped with the fingers. Fortunately, also, it was found that the position assumed by the fragments is fairly uniform if breaking occurs at the usual site. The lower fragment rides up along the spur of the bone, and angulation of about 15 degrees, or less, occurs. Bones healing in this position can be placed under the yoke uniformly, and the weight adjusted to the apex of the callus. The only significant variation occurs when the angulation is more acute and the bone shifts position so that the force is applied at the inner point of the angulation. Such readings have been discarded.

Figure 2 shows the method of recording each experimental fracture, and examples of the results obtained. In each, the line across the bone represents the line of fracture and the arrow the angulation of the lower fragment. Numbers 15 and 17 represent the typical fractures, with typical displacement. Number 18 is an example of an unusual line of fracture at the usual site with displacement so typical as to permit adjustment in the apparatus in such a manner as to bend and break the callus in the usual way. Numbers 16 and 28 show typical positions of the fragments and angulation slightly in the reverse direction. These

also were susceptible of accurate measurement. Number 21 is an example of an unsatisfactory result, which was discarded. Here the fracture is at an abnormal site, and sharply angulated.

When adding weight to healing bones, there is a slow bending, through an arc on the scale of 1 to 15 cm. This bending is uniform at first. Later, it becomes more rapid, until it finally ends in the complete rupture of the callus.

After a total experience with about seventy-five rats, in all of which both humeri were studied, the method appeared sufficiently accurate to be of value for the ends desired.

The preliminary studies revealed that the most favorable stage in healing for rats of the age used (from 7 to 11 weeks, at the time of breaking the bones) was at fourteen days.

#### EXPERIMENTS

All of the experiments were, therefore, performed in accordance with the following general scheme. The litter was divided into control

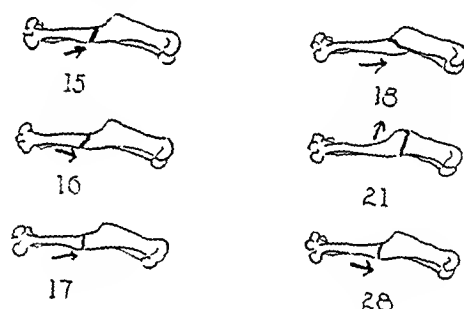


Fig. 2.—Typical and atypical lines of fracture and angulation. Compare text

and experimental animals. The latter group was redivided in the different experiments, as indicated below. If dietary modifications were to be made, these were carried out on the experimental animals for the specified time, at the conclusion of which the entire litter was anesthetized and the left humerus of each animal was fractured. If no dietary modification were to be made, the breaking was done at the corresponding age. The experimental animals were then subjected, for a period of fourteen days, to the various procedures to be detailed. At the end of this time, the entire litter, control and experimental animals, were killed with ether. Both humeri were dissected out, with care not to disturb the integrity of the bone or of the callus, and the breaking strength of each was measured. The line of fracture and the angulation were recorded at the same time on diagrams, such as those reproduced in Figure 2.

As there was marked variation in animals of the same litter in the absolute breaking strength of the undamaged bone, expressed in grams,

the results can better be expressed in ratios, by dividing the breaking strength of the healing bone by the breaking strength of the undamaged bone. This method has given results of fair uniformity in the control animals of each litter, as shown in Table 2. The greatest variation within one litter is seen to be 0.10 in Litter B. It is to be noted here that the animals of Litter F, in which the most rapid healing occurred, were younger by two weeks than those of any of the other litters. The high reading in Litter C was on a single rat.

Six litters were used, totaling fifty-two rats. Of these, eighteen animals, including an entire litter, were discarded because of failure to obtain a satisfactory fracture. In the discarded litter, in which the rats were two weeks younger than the youngest of the others, the breaking point in the bone occurred near the head, there was no displacement, and union was too far advanced at fourteen days to make the results comparable.

TABLE 2—RESULTS WITH CONTROL ANIMALS

Litter	Age in Weeks at Breaking Bone	Rat 1	Rat 2	Rat 3	Average Per Litter
D	11	0.58	0.56	0.55	0.56
F	7	0.73	0.76	0.70	0.73
A	9½	0.67	0.64		0.64
B	9½	0.56	0.47	0.57	0.53
C	9	0.73			0.73
General average, 12 rats					0.64
Control Rats of normal bone	Strength of fractured bone expressed in percentage of strength of normal bone				

When sunlight was to be employed, the rats were placed in the direct rays without interposition of glass during most of each afternoon, at least four hours daily and often six.

#### PROTOCOLS

Percentages represent the relation of the breaking strength of the callus to that of the normal bones, as in Table 2. Diet 3143 wherever it occurs in these protocols, refers, as elsewhere in this paper, to the diet devised by McCollum and his associates.<sup>7</sup>

#### I ON NORMAL DIET

LITTER D—Age at breaking of bones, 11 weeks, age at measuring strength of callus, 13 weeks

Controls 3 rats, average, 0.56

Sunlight (2 weeks) 3 rats, average, 0.53

Normal Diet Plus Cod Liver Oil 3 rats, average 0.54

<sup>7</sup> Footnotes 4 and 5

LITTER F—Age at breaking of bones, 7 weeks, age at measuring strength of callus, 9 weeks

Controls 3 rats, average, 0.73

Sunlight (10 days) 3 rats, average, 0.62

## II ON ABNORMAL DIET

LITTER A—Age at beginning of dieting, 6 weeks, age at breaking of bone  $9\frac{1}{2}$  weeks, age at measuring strength of callus,  $11\frac{1}{2}$  weeks

Controls (normal diet throughout) 2 rats, average, 0.65

Controls (Diet 3143 from age of 6 weeks) 2 rats, average, 0.54

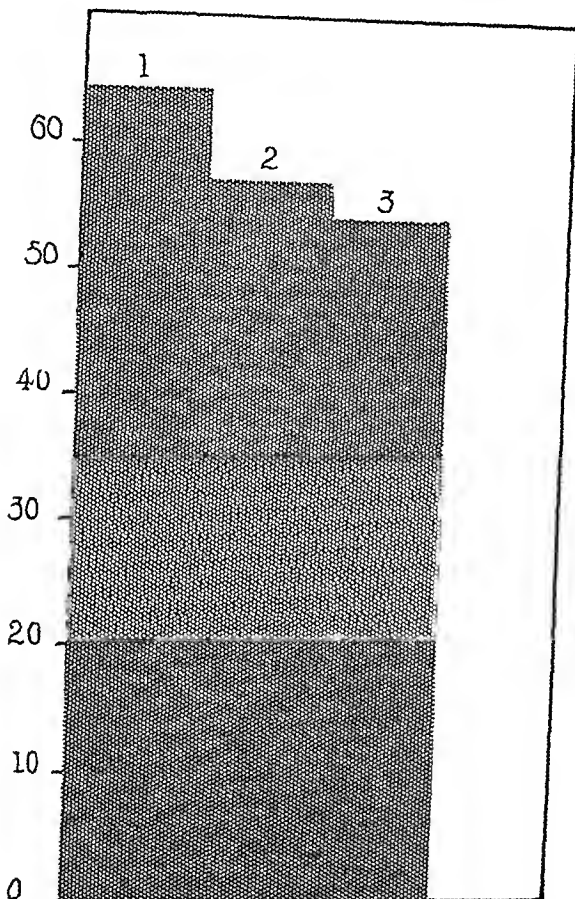


Fig 3—Consolidated averages of experiments under normal dietary conditions. Column 1, normal controls 12 rats, 0.64, Column 2, normal diet plus sunlight 6 rats, 0.57, Column 3, normal diet plus cod liver oil 3 rats, 0.54

Sunlight (for 2 weeks immediately following fracture, Diet 3143 from age of 6 weeks) 1 rat, 0.63

Cod Liver Oil (Diet 3143 from age of 6 weeks cod liver oil added after fracture) 1 rat, 0.47

LITTER B—Age at beginning of dieting, 6 weeks, age at breaking of bones,  $9\frac{1}{2}$  weeks, age at measuring strength of callus,  $11\frac{1}{2}$  weeks

Controls (normal diet throughout) 3 rats, average, 0.53

Controls (Diet 3143 from age of 6 weeks) 2 rats, average, 0.52

Sunlight (for 2 weeks immediately following fracture, Diet 3143 from age of 6 weeks) 1 rat, 0.55

Cod Liver Oil (Diet 3143 from age of 6 weeks, cod liver oil added after fracture) 1 rat, 0.51

LITTER C—Age at beginning of dieting, 5½ weeks, age at breaking of bones, 9 weeks, age at measuring strength of callus, 11 weeks

Controls (normal diet throughout) 1 rat, 0.73

Controls (Diet 3143 from age of 6 weeks) 3 rats, average, 0.53

Sunlight (for 2 weeks immediately following fracture, Diet 3143 from age of 6 weeks) 1 rat, 0.38

Cod liver Oil (Diet 3143 from age of 6 weeks, cod liver oil added after fracture) 1 rat 0.32

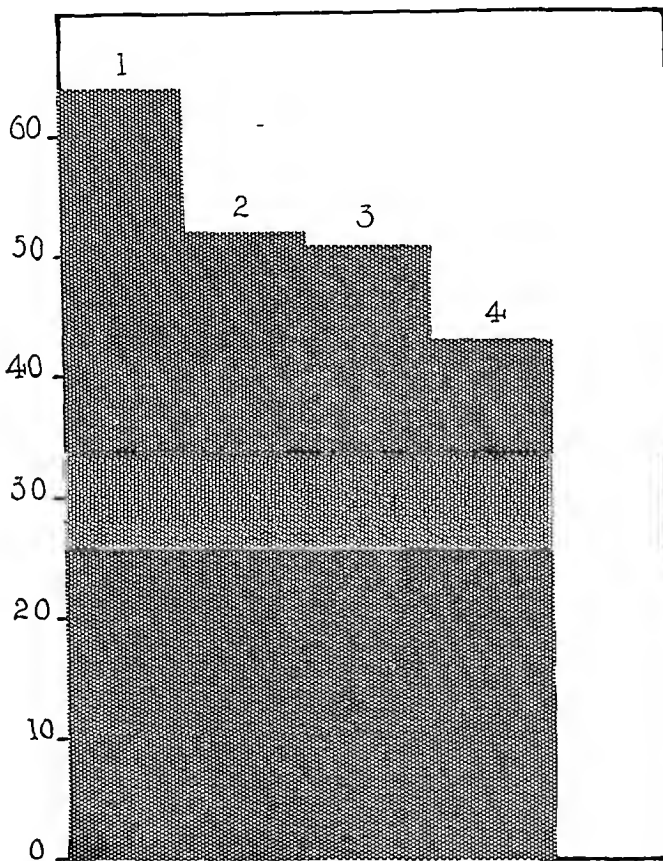


Fig 4—Consolidated averages of experiments under abnormal dietary conditions Column 1 normal controls 12 rats, 0.64, Column 2 controls, Diet 3143 7 rats, 0.53, Column 3, Diet 3143 plus sunlight 3 rats, 0.52, Column 4 Diet 3143 plus cod liver oil 3 rats 0.43

#### COMMENT

A study of these protocols reveals that in no instance did the addition of cod liver oil to the diet of rats, either on a normal diet or on a rickets producing diet, result in a greater strength of the callus. In two litters A and C, the callus of control rats on a rickets producing diet was somewhat less strong than in the normal controls, that is, from 0.54 to 0.65 and from 0.53 to 0.73, but cod liver oil did not tend to correct this defect in any instance.



Further, in the rats on a normal diet, sunlight had also no effect in accelerating the calcification of callus. In the rats on Diet 3143, in one series (Litter A), the effect of sunlight seemed favorable, but it must be remembered that the greater strength of the callus in the rat exposed to sunlight as opposed to that in the dieted control animal, that is, from 0.63 to 0.54, is within the limits of variation of the method as expressed in Table 2.

When, considering the averages of each litter as a coordinate unit, we consolidate these results, we obtain the graphic representations shown in Figures 3 and 4.

#### CONCLUSIONS

1. Exposure to sunlight and the addition of cod liver oil to the diet exert no measurable accelerating influence on the calcification of fracture callus in normal rats.

2. The same factors are equally nonoperative under experimental conditions in which such favorable effects might be expected to be intensified.

# A STUDY OF DIVERTICULUM FORMATION IN THE APPENDIX

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NEW YORK

The subject of diverticulum formation in the appendix has apparently aroused the interest of but few writers in Europe and America. It seems rather astonishing in these days of experimental investigation of almost every conceivable subject that this interesting, if relatively unimportant, process has never, so far as I can ascertain, been produced or studied experimentally. Hypotheses have been based on morphologic observations of the appendix itself, together with the application to the appendix of a few experiments made in the large and small intestine. The results are unsatisfactory because some of them, reported by earlier observers, either could not be reproduced, or produced entirely different and contradictory results, when repeated by others.

It seems, therefore, that this condition deserves further investigation, particularly so inasmuch as I have become convinced during the past year that the condition is not nearly so infrequent as the few reported cases would lead one to believe. When, coincidentally with the change in the method of examining the appendixes in the laboratory of surgical pathology at the Presbyterian Hospital, we found five examples of diverticulum formation in the appendix in one year, whereas in the ten preceding years there was a record of only one appendix with a diverticulum, the inference is justifiable that many cases must have been overlooked. It was formerly our custom to make two or more transverse sections of the appendixes sent for examination, until the discovery of a case of multiple diverticula aroused our interest in making a careful search for this condition, and we began to section all the appendixes longitudinally in a plane passing through the mesenteric and anti-mesenteric borders. Four more appendixes came to our attention in this way, none of which were suspected or observed by the surgeons who removed them.

The questions which naturally arise in connection with diverticula of the appendix are: (1) Have they any clinical significance? (2) What are their morphologic characteristics and what are the factors which lead to their formation? (3) Is there any way in which they may be diagnosed clinically? (4) Can their formation be prevented, or, if they

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\*From the Laboratories of Surgery at the College of Physicians and Surgeons, Columbia University, and the Laboratory of Surgical Pathology, Presbyterian Hospital, New York. Drawings by Alfred Feinberg.

have formed, is any treatment indicated? Most of those who have written about diverticula of the appendix have concerned themselves almost exclusively with the second of these questions, while a few have speculated about the first. This paper will deal very largely with the second question.

The discussion which follows is based on (*a*) the study of seven appendixes with diverticula, six of which were removed operatively at the Presbyterian Hospital, New York, and one at necropsy at the Bellevue Hospital by Dr. B. Morgan Vance and kindly given to me by him for study, (*b*) the reexamination of a large number of appendixes removed operatively at the Presbyterian Hospital during the last eleven years, for certain morphologic and pathologic characteristics which seemed to have some bearing on the formation of diverticula, (*c*) certain experiments on dogs, the results of which are suggestive in attempting to determine some of the etiologic factors, (*d*) a study of all the literature to which I could obtain access, with the desire both to learn what other investigators have observed and deduced and to ascertain from the photographs and drawings reproduced whether certain morphologic peculiarities which are apparent in the series reported in this paper were also present in other appendixes.

Before attempting to analyze the factors which seem to favor the formation of diverticula of the intestinal tract in general and of the appendix in particular, it will be pertinent to define what is understood by the term and to review briefly the hypotheses which have been advanced up to the present to explain them.

#### DESCRIPTIVE DEFINITION, STATISTICS AND HYPOTHESES OF DIVERTICULUM FORMATION

Most writers are agreed that diverticula in the appendix are "evaginations," "protrusions," "herniations," etc., of the mucosa, muscularis mucosae and submucosa through defects in the muscular coat. They are all said to be of the "acquired" variety, in contradistinction to the congenital diverticula which may be found in the intestinal tract, such as Meckel's diverticulum, in the walls of which are to be found all the coats which are present in the wall of the intestine. Such congenital diverticula have never been noted in the wall of the appendix.<sup>1</sup> They may be single or multiple. They are most commonly found along the mesenteric border, bulging out between the leaves of the mesenterium. Less commonly, they occur along the antimesenteric border and at the tip, very rarely elsewhere. In regard to frequency,

<sup>1</sup> Krabbel. Divertikelbildung bei Appendicitis, Beitr. z. klin. Chir. 80  
121, 1912.

MacCarty and McGrath<sup>2</sup> report seventeen in 5,000 appendixes (0.34 per cent), Konjetzny<sup>3</sup> found two in 1,000 cases (0.2 per cent), Moschcowitz,<sup>4</sup> four in 1,500 (0.26 per cent) and Mertens<sup>5</sup> in 106 necropsies found two appendixes with diverticula, and in twenty-eight appendixes removed at operation, one diverticulum (together, 2.23 per cent). If we take the five cases (Cases 1 to 5, inclusive) found in the one year, from July 1, 1921, to June 30, 1922, during which time 264 appendixes were removed at the Presbyterian Hospital, the percentage is 1.89.

The diverticula usually range in diameter from 3 to 5 mm. Rarely, if ever, do true mucosal lined diverticula reach a larger diameter than 1 cm, although mucocèles may reach a much greater size. They are evenly divided between males and females. The youngest patient apparently was Wilkie's,<sup>6</sup> a 15 year old girl, while MacCarty and McGrath<sup>2</sup> found one in a patient 64 years old. Usually, they have been found in appendixes acutely or chronically inflamed, occasionally, they have been found at necropsy or in patients operated on for some unrelated trouble. Reference to the accompanying statistical table will reveal that the cases reported here conform to these observations without any important variations, except a morphologic one which will be referred to later.

Of the acquired type, two groups are recognized: (1) those that are said to occur through the defects in the muscular coats which are found along the mesenteric and antimesenteric borders of the appendix, and through which pass the vessels which supply the submucosa and mucosa, and (2) those which occur through defects in the muscular coats which are results of acute inflammatory processes. Thus, there may be an intramural abscess which destroys the muscularis but which heals without perforation, leaving a scar in the muscularis through which the protrusion may subsequently occur, or there may be perforation with protrusion of the mucosa at the same time and, subsequently, subsidence of the acute inflammatory process without removal of the appendix. The last process may lead to the formation of an external mucocèle, i. e., a subserous or intramesenteric collection of mucus in a cavity lined

2 MacCarty, W. C., and McGrath, B. F. Clinical and Pathologic Significance of Obliteration, Carcinoma and Diverticulum of the Appendix, *Surg Gynec & Obst* **12** 211 (March) 1911.

3 Konjetzny. Zur Pathologie und Klinik der erworbenen Wurmfortsatzdivertikel, *München med Wchnschr* **56** 2251, 1909.

4 Moschcowitz, E. The Pathologic Diagnosis of Diseases of the Appendix, *Ann Surg* **63** 697 (June) 1919.

5 Mertens. Falsche Divertikel, etc., *Mitt a d Grenzgeb d Med u Chir* **9** 743, 1902.

6 Wilkie. Carcinoma of the Appendix Causing Diverticula of the Appendix and Acute Appendicular Obstruction, *Brit J Surg* **8** 392 (April) 1921.

with connective tissue which communicates with the lumen of the appendix by a tract lined with mucous membrane extending through the muscularis <sup>7</sup>

All of the foregoing statements are based on morphologic observations. The diverticula have been seen, and, as they were all accompanied by defects in the muscularis, it was assumed that muscular defects must precede their formation. The only muscular defects which could be found were those through which the vessels passed and those which were the result of damage following infection, ergo, the diverticulum must take place through these defects.

In order to explain why protrusions of mucous membrane occur through these defects in some appendixes and not in others, various hypotheses have been advanced. Most of them were used in an attempt to explain the occurrence of diverticula in the intestine, but they have been applied to those occurring in the appendix as well.

Klebs <sup>8</sup> states that, in obese people, collections of fat about the vessels as they pass through the wall tend to shove the muscle bundles apart, thus increasing the diameter of the defect and increasing its potential weakness. Graser <sup>9</sup> suggests that the chronic distention of the blood vessels as they pass through the muscular coats tends to push aside the muscle bundles, in this way increasing the diameter of the defect.

Practically all of the authors who attempt to account for the force which tends to drive the mucosa and submucosa through the muscularis speak of increased intraluminal tension. Edel <sup>10</sup> suggests chronic constipation with fecal distention of the large bowel as a source of this increased tension. Beer <sup>11</sup> believes that, in addition to constipation and chronic distention of the large bowel, it is necessary to have the muscular degeneration and weakness which are coincident with old age. Wilkie <sup>6</sup> states that the obstruction of the lumen of one of his appendixes by a carcinoma was sufficient to explain the occurrence of a diverticulum distal to it.

When one attempts to analyze these hypotheses and apply them to appendix diverticula, it is found that, while each one of them may be applicable to a few cases, none of them has a universal application. Klebs' suggestion that the vascular defects in the muscularis are

7 Villar. Sur un cas d'appendicite chronique avec pseudo-myxoma diverticulaire, Bull de l'Acad de med **79** 175, 1819

8 Klebs. Path Anat, 1869, p 271

9 Graser. Ueber multiple falsche Darmdivertikel in der Flexura sigmoidea. Munchen med Wchnscher **46** 721, 1899

10 Edel. Ueber erworbene Darmdivertikel, Virchows Arch f path Anat **138** 347, 1894

11 Beer, E. Am J M Sc **128** 135 (July) 1904

increased in diameter by accumulations of fat about the vessels obviously loses its force when the diverticula occur, as they usually do, in people who are not obese Graser's hypothesis that chronic distention of the blood vessels in the vascular defects tends to shove aside the muscle bundles, thus increasing the diameter of the defects, does not apply to any of the appendixes with diverticula that I have seen or read about In these, where there have been broad defects, they have been filled with dense connective tissue, surrounding several rather small and thick walled vessels, which were not distended It might be argued that these had collapsed after removal, but a majority of the appendixes which we receive for examination in the laboratory reach it with their vessels distended, so this is probably not a valid objection In any event, this hypothesis has no bearing on the inflammatory defects There is no proof that chronic constipation and fecal distention per se cause increased intraluminal tension, and it can be definitely stated that diverticula of the appendix at least may occur in people in whom there is no clinical evidence of chronic constipation or fecal accumulation in the large bowel Beer's suggestion that weakening of the muscle, due to old age, is an etiologic factor is rarely applicable to the appendix diverticula, most of which occur in vigorous adults, and examination will show that the muscular coats are, in almost every case, above the average in thickness It is probably true that there is some obstruction to the lumen proximally in a majority of appendixes with diverticula, but there are just as certainly others in which there is no demonstrable obstruction, and, therefore, this cannot be regarded as an etiologic factor of universal application

The importance of increased hydrostatic tension within the lumen of the intestine as a factor in the etiology of diverticula of the intestine (and, by inference, of the appendix) received strong support through the publication, in the latter part of the nineteenth century, of some experimental work that has since been completely discredited, but the influence of which can still be traced in recent articles on the subject Heschl,<sup>12</sup> Hansemann<sup>13</sup> and Grassberger<sup>14</sup> distended segments of the large intestine with water, and asserted that they saw bulgings along the mesenteric border, which disappeared when the tension was released They asserted that these occurred at the defects in the mesenteric border through which the vessels pass, and they argued from this that these were weak points through which diverticula might occur in the living intestine, if the increased intraluminal tension were chronic Beer<sup>11</sup> was

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<sup>12</sup> Heschl *Wien med Wchnschr* 30 1, 1880

<sup>13</sup> Hansemann *Ueber die Entstehung falscher Darmdivertikel*, *Virchows Arch f path Anat* 144, 1896

<sup>14</sup> Grassberger *Ein Fall von multiplex Divertikelbildung*, *Wien med Wchnschr* 10 149, 1897

unable to reproduce these bulgings experimentally, and it is probable from Chlumsky's observations that they are at best a phenomenon of dead intestine only. Heschl,<sup>12</sup> Hanau<sup>15</sup> and Good,<sup>16</sup> using human necropsy material, several hours after death, found that, after extreme distention, the intestine burst regularly between the leaves of the mesentery. This observation has been used as an argument to support the hypothesis that the mesenteric border is the weakest portion of the intestine wall, and that perforations and diverticula are therefore more liable to occur in this region than in any other. Chlumsky,<sup>17</sup> however, showed the fallacy of using dead material for investigation by repeating this experiment, using the living dog's intestine within the body. He found that it burst regularly along the antimesenteric border. When he used dead intestine, removed from the body, he found that it burst between the leaves of the mesentery. We are thus left with inconclusive evidence, so far as these experiments are concerned, when we attempt to apply them to determine the forces which tend to produce diverticula in the appendix and the intestine.

The only observations which, it seems to me, can altogether survive critical analysis are the morphologic ones that diverticula are always associated with defects in the muscularis and that the only defects which have been observed are those due to perforation, to scarring following suppurative inflammation and the normal ones in the mesenteric and antimesenteric borders through which vessels pass. There is no proof that diverticula occur through these defects, but all the evidence that we have favors the assumption that they do, and, therefore, it seems fair to accept it as a working hypothesis.

If we turn now to the seven appendixes described in this paper, a reference to Figures 1, 2, 3, 5 and 6 demonstrates very clearly a condition which has not been described before in the literature, possibly because in most of the cases reported the specimens were sectioned transversely instead of longitudinally. In these diverticula, it will be seen that, not only the mucosa and submucosa nearest the muscular defect have passed through it to form an extra muscular sac but also the mucosa and submucosa from the side opposite the muscular defect have passed through it, thus, in effect, diverting the entire lumen outside the appendix into the diverticulum sac.<sup>18</sup> This condition was noted in four diverticula in four different appendixes out of a total of eighteen

15 Hanau. Falsche Darmdivertikel, *Virchows Arch f path Anat* **138**, 1894, *ibid* **145** 172, 1896.

16 Good. Aus dem Leichenhause des Cantonspitals zu Gallen (Dr Hanau), *Inaug Diss*, Zurich, 1894.

17 Chlumsky. Ueber verschiedene Methoden der Darmvereinigung, *Beitr z klin Chir* **25** 539, 1899.

18 Several of the diverticula illustrated by MacCarty and McGrath (Foot-note 2) seem to show this condition, but no reference is made to the phenomenon in the text.

diverticula in seven appendices. The same diversion of the lumen outside the muscularis can be seen in the appendix which had ruptured two years before it was removed, eversion of the mucosa into an abscess cavity resulting, with the proximal and distal portions of the appendix opening into it separately through the muscular defect (Fig 13)

All of the hypotheses which have been advanced to account for the motive force which pushes the mucosa through the muscular defects depend on a distention of the lumen. The existence of these four diverticula, however, forces us to seek some additional explanation to account for them. It is inconceivable, for me at least, to imagine that the force exerted by the expansion of a fluid or a gas within the lumen of an appendix could *alone* be sufficient to force the entire circumference of the mucosa and the submucosa through a defect in the muscularis. Some other force must be operative in these cases and probably in all the rest of the cases of diverticulum formation as well.

A little reflection will make it apparent that most of the comments and reasoning up to this point have been based on morphologic and mechanical considerations almost exclusively. We have talked of diverticulum formation as if it took place by the action of a force in an inert, lifeless tube made up of tissues of different tensile strength but without any other characteristics. This neglect of the biologic factor has resulted in the neglect of the tremendous energy transformations which are occurring constantly in the appendix and intestine throughout life, it has allowed constant morphologic references to the smooth muscle tissue of the appendix but scarcely any physiologic ones<sup>19</sup>. In other words, the force exerted by the contraction of the smooth muscle tissue in the appendix during life has not yet been considered as an important factor in the etiology of diverticulum formation.<sup>20</sup>

#### MORPHOLOGIC AND EXPERIMENTAL EVIDENCE IN FAVOR OF THE MUSCULAR CONTRACTION HYPOTHESIS OF DIVERTI- CULUM FORMATION

Inasmuch as no one, as far as I can find out, has investigated the possibilities of this force in connection with appendiceal diverticula, it

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<sup>19</sup> Seelig (Footnote 26) in a single phrase suggests that the contraction of the smooth muscle plays some part in diverticulum formation in the appendix, but does not develop the theme.

<sup>20</sup> It is all the more astonishing that this should be so when one finds that it has been considered in reference to diverticula elsewhere in the body. Forty-five years ago, Zenker (quoted by Judd, *Esophageal Diverticula*, Arch Surg 1:38 [July] 1920) described the pharyngo-esophageal dimple just behind the cricoid cartilage on the posterior wall, where there is a weakened point due to the arrangement of the musculature at the junction of the upper esophagus and the lower end of the pharynx. He noted that diverticula occur through this, and believed that the increased pressure exerted on the weak point during the act of swallowing was the chief etiologic factor.



seemed as if it were worth attempting. With this purpose it was determined to state a theorem in regard to diverticulum formation and then to see whether it would serve to explain all the known phenomena. If it did so this would not prove it true, because we know by observation only a few of the phases of the process. If supported by the facts, however, it would make it at least a more satisfactory hypothesis than any which has been advanced before, because, as has been indicated, none of them serve to explain all of the known phenomena.

It has been assumed, therefore, that diverticula take place through defects in the muscular coats, and that the chief motive force that drives the submucosa and mucosa through these defects is that exerted by active contraction of the longitudinal and circular muscles on the submucosa, mucosa and contents of the lumen. With this in mind, a morphologic examination of a number of appendixes has been made and certain experiments have been performed, with the hope that the results would suggest whether the hypothesis was credible or not.

In order to understand the process of diverticulum formation, it is necessary to emphasize certain well known mechanical and physiologic facts. One must first recall the physical relationship which the coats of the appendix bear to one another. The mucosa and the submucosa, with the muscularis mucosae running between, form a single coat, the three parts of which are intimately bound together. The muscularis, subserosa and serosa likewise form a more or less homogeneous whole. But, in many appendixes, especially those which have not been previously badly damaged by inflammation, the attachment between the submucosa and muscularis is by loose bonds of areolar and elastic tissue, so that the two coats are capable of a certain amount of excursion, one upon the other.

The muscular coats of the appendix are divided into an outer longitudinal coat and an inner circular coat, the latter usually much thicker than the former. Under normal conditions of tonus, unless widely distended by inspissated feces, fluid or a fecolith, the mucosa and submucosa in many appendixes are maintained within the circular muscle in a plicated state, both transversely and, to a less extent, longitudinally. When there is a loose attachment of the submucosa to the muscularis, it allows free play between these two coats. With strong muscular contractions, the tendency is to exaggerate these folds by reducing both the diameter and the length of the appendix. If an appendix or intestine is fixed in a state of strong muscular contraction and then sectioned longitudinally, these exaggerated folds can easily be seen.

With these observations in mind, let us suppose that there is a weak point in the muscular wall of the appendix and the muscle contracts: what may happen? In order to answer this question, we are forced to use animals, because it is improper to use the living human appendix in

situ for experimental purposes While dogs' appendixes are too much like exaggerated cecal pouches to be altogether satisfactory for experimental purposes, I was forced to use them because I was unable to procure organs more nearly resembling the human Reference to Experiments 1 to 5 will show that, if a muscular defect is made in the wall of a dog's appendix by incising down to the submucosa or by excising a piece of subserosa and muscularis, there is, following the injury, a strong contraction of both circular and longitudinal muscles, and, at the same time, the mucosa and submucosa protrude through the muscular defect, forming a diverticulum<sup>21</sup> This can persist for some days If the same thing is done to an appendix sufficiently long after death for the muscular tissue to lose its contractility, no such protrusion will occur, *provided the appendix or intestine is not distended* If it is distended, the protrusion may occur (Experiment 5)

From these experiments, we see that, with a suddenly produced unfilled gap in the muscularis of a dog's appendix or intestine, because of the free play between the submucosa and the muscularis, the mucosa and submucosa may be protruded by muscular action and may also be protruded by the force of fluid tension acting from within the lumen We can go a step farther in studying the effects of muscular contraction and distention If an appendix with a protrusion of mucosa and submucosa through an experimentally produced gap in the muscularis due to muscular contraction is distended moderately, the diverticulum fills with fluid and stands out more clearly as a smooth rounded hemisphere If the internal hydrostatic tension is considerably increased, the diameter of the appendix gradually increases, the coats of the appendix become thinner as they are stretched, the gap in the muscularis increases in width and the *diverticulum grows steadily less until it disappears entirely* (Experiment 4) This effect is produced apparently because the increased internal hydrostatic tension overcomes the force of muscular contraction and stretches and thins the muscular coats until they are forced outward to as great a distance as the original diverticulum In a dog's dead intestine, in the body, increased intraluminal

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21 When this procedure was repeated, using a human appendix which had just been removed from the body and which showed very moderate chronic inflammatory changes, the same bulging of the mucosa and submucosa through the muscular defect occurred In this case, the bulging was only 1 mm beyond the serosal level (Experiment 6) Some years ago when Dr Lewisohn (Clinical and Experimental Studies on Congenital Pyloric Stenosis, Surg, Gynec & Obst 26 320 [March] 1918) was doing some experimental Rammstedt operations on the dog's pylorus, in one case, the operation was followed by diverticulum formation It seems probable that, in this situation, it was due more to muscular contraction than to distention, as the pylorus is probably very rarely distended (compare illustration in his article)

tension at first forces the mucosa and submucosa out through the gap in the muscularis, making a diverticulum, with marked increase in the tension, the appendix dilates enormously, and the diverticulum disappears as described above (Experiment 5)

We are now in a position to state that a diverticulum may occur through an experimental defect in the muscularis of a dog's appendix, both as the result of intraluminal distention and as a result of muscular contraction. Increased muscular contraction increases the tendency for the mucosa to be protruded, while greatly increased intraluminal tension tends to diminish and, eventually, to cause the disappearance of the diverticulum.

With these suggestive animal experiments in mind, let us turn back to the human appendix to see whether a morphologic consideration of a number of appendixes will support the hypothesis that muscular contraction is the chief factor in the causation of diverticula of the appendix and, at the same time, strengthen the view that in many cases the vascular defects are the weak points in the muscularis through which the protrusions occur.

The arteries and veins which supply the appendix reach that organ at from six to eleven different points along the mesenteric border. They send branches that pass through the muscular coats and form a rich anastomotic network in the submucosa. Other branches pass circumferentially in the subserosa, and, at the antimesenteric border, these also pierce the muscular coats and join the submucosal anastomosis. A few small twigs pass into the muscularis between the mesenteric and antimesenteric borders, but they are apparently for the supply of the muscularis itself and do not pierce it. The vessels as they pass through the muscular coats are surrounded by a greater or less amount of connective tissue and sometimes by a few fat cells. When seen, these vascular defects are always larger and much more prominent on the mesenteric than on the antimesenteric border. Usually, the vessels pass through at right angles to the long axis of the appendix, less often, they pass through tangentially. When found in the appendixes examined, they varied between 0.5 and 1 mm. in thickness on the mesenteric border, and were always less than 0.5 mm. on the antimesenteric border.

In examining the appendixes with diverticula in the series reported in this paper, it was noted in all of the cases that the muscular coats appeared above the average in thickness, while in all but one the vascular defects were very prominent and easily visible.<sup>22</sup> An attempt was made to determine the relationship between the width of the vascular defect

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<sup>22</sup> In the one exception, the diverticulum was believed to have followed an inflammatory weakening of the wall rather than to have occurred through a vascular defect (Case 7).

and the thickness of the musculature in the appendix. Ninety-six appendixes were chosen at random as they were received in the laboratory of surgical pathology, and the thickness of the muscular coat was measured by a millimeter scale. The average thickness was 0.86 mm, a figure slightly above the 0.5 to 0.75 mm which Aschoff<sup>23</sup> says is the variation in normal adult appendixes. During the routine gross examination of these appendixes, it has been a laboratory rule that the appendix shall be bisected longitudinally in a plane passing through the mesenteric and antimesenteric borders, and the presence or absence of the vascular defects noted in the report. When the defects are of any size, the vessels are surrounded by dense connective tissue, which shows up as a dull white band, in sharp contrast to the much darker semi-translucent muscularis. It is not unreasonable to assume, therefore, that, in those cases in which the defects were seen, they were probably broader and contained more connective tissue than in those in which they were not seen. In the forty-two cases in which they were seen, the average thickness of the muscularis was 1.06 mm (the thinnest, 0.5, and the thickest, 3.0 mm), while in the fifty-four cases in which the vascular defects were not seen, the average thickness of the muscularis was 0.71 mm (the thinnest, 0.3, and the thickest, 1.5 mm).<sup>24</sup> The average diameter of the vascular defects in the mesenteric border in the forty-two cases in which they were seen was 0.5 mm.

Turning to the series of seven appendixes with diverticula, we find the average width of the muscularis 1.91 mm (the thinnest, 1, and the thickest, 2.7 mm). In Cases 1 to 6, inclusive, in which the mesenteric vascular defects were noted passing through the muscularis, the average diameter of the largest defects noted in each case was 1 mm (the largest, 1.5, and the smallest, 0.5 mm).

These figures suggest that appendixes vary considerably in the thickness of their muscular coats and that the broader vascular defects which are more easily visible with the naked eye are found in the more thickly muscled appendixes. They also indicate that the muscularis of those appendixes in which diverticula are formed averages a whole millimeter thicker than in the average appendix removed at operation, and that the mesenteric vascular defects in the appendixes with diverticula tend to be broader than the average.

We cannot satisfactorily account for this muscular thickening in every case by the hypothesis that it is hypertrophy resulting secondarily

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23 Aschoff, L. *Die Wurmfortsatzentzündung*, Jena, 1908, pp. 10 and 72.

24 Of course, these figures have only comparative value because of the many variables and sources of error, the greatest being the edema of the muscularis in acute cases. But, as the same factors of error are operative in both series, it is felt that the value of the results for comparison is not vitiated.

from obstruction of the lumen and increased function of the muscular tissue, this increased function being stimulated by accumulation of contents within the lumen, because, while in five of the seven cases there was either actual or potential obstruction of the lumen proximal to the diverticula, in two (Cases 4 and 6), there was neither, and both of these had thick muscular coats. So, while admitting the attractions of this hypothesis and suggesting with Wilkie " that it plays some part, it must be admitted that some other factor or factors are involved. In any event one cannot escape from the suggestion that these thick muscles indicate increased function and that they are capable of more powerful contraction, and hence of exerting a more powerful force, than the thinner ones.

It will not be unprofitable, at this point, to reconsider the question of diverticulum formation as a result of damage to the wall of the appendix from suppurative inflammation. As we have seen, it has been stated, first, that an intramural abscess may form, destroy the muscularis, drain into the lumen of the appendix, and subsequently be replaced by scar tissue, thus leaving a defect through which it is conceivable that a diverticulum may pass, second, that, during an acute inflammatory attack, the appendix may perforate, and, as a result of the perforation, a diverticulum or mucocele may develop. All that can be adduced to support the first statement are the observations that intramural abscesses occur, that scars occur in the muscularis, and that diverticula occur. All of the intervening steps are suppositious. In regard to the second, however, we are able to demonstrate more of the intervening steps, and it will be worth while to do this because of the light which it seems to throw on the dynamics of the process.

It must be recalled that the vast majority of perforations of the appendix are associated with extensive necrosis of the mucous membrane. Most perforations appear as holes lined with necrotic tissue, leading through the wall from a lumen also largely lined with necrotic tissue. Occasionally, however, we find the condition of affairs illustrated in Figure 12, in which there is a wide perforation without extensive necrosis, which has resulted in the protrusion and eversion of the mucosa and submucosa (Case 8). A condition analogous to this, but of two years' standing, can be seen in Figure 13, which has been referred to before. There we find perforation, with protrusion through the perforation not only of the adjacent mucosa but also of the entire lumen, so that the proximal and distal portions of the lumen open separately into the extra-appendiceal abscess (Case 9).

Figure 4 presents a tract lined with mucous membrane leading to a cavity in the mesenteric lumen near the tip, filled with mucus and pus and lined with granulation tissue. As there is a diverticulum in another part of this appendix, this may be thought of either as a diverticulum in

which the acute inflammatory process has destroyed its lining mucosa or (and this appeals to me as more probable) it may be considered that, as the result of an acute inflammatory process in the appendix wall, possibly during a previous attack, a perforation and partial protrusion of the mucosa occurred with the formation of a mucocele, and that the inflammation present when the appendix was removed involved a previously formed sac

The speed and ease with which mucosal defects in the intestine can regenerate is well known, so that it requires no great stretch of the imagination to surmise that, in Cases 8 and 9, had there been a subsidence of the infection, perhaps by free and adequate drainage of the abscess through the fistulous tract leading back through the wall of the appendix into the lumen and so on into the cecum, a regeneration of mucosa might have lined the extramuscular sacs, giving the picture seen in other diverticula in this paper, in the latter case with a single opening into the lumen, in the former with a double opening. Figure 11 illustrates a diverticulum near the tip of an appendix that may very well have occurred in this way

Figure 12 illustrating a fresh perforation, with protrusion of the mucosa and eversion, cannot fail to recall, to all who have seen it, the behavior of the mucosa of any part of the living gastro-intestinal tract when the entire thickness of the wall is cut through and the lumen entered. It will be remembered that, coincidentally with the wide gaping of the wound, the mucosa protrudes and, as it comes out, turns back on itself so that it both projects beyond the surface of the serosa and still allows the cut edge of the mucosa to lie in contact with the cut edge of the serosa. If the same cut is made in a dead intestine, none of these phenomena occurs. In this case, we cannot blame the intraluminal tension, for, as soon as the lumen is entered, the intraluminal and extraluminal tensions are equalized. We are therefore compelled to fall back on the force of muscular contraction which responds to the irritation incident to the trauma of the incision. The segment cut into is narrowed and shortened by the contraction of the circular and longitudinal fibers, which, in turn, forces the redundant mucosa and submucosa through the opening, and, because the submucosa is attached to the muscularis while the mucosa is a free, unrestrained surface, eversion occurs. The similarity between this experimental end-result and the perforations illustrated in Figures 12 and 13 is so striking that I believe we are justified in adopting the hypothesis that the force resulting from muscular contraction is the chief factor in producing the eversion of the mucosa and submucosa

#### SUMMARY

The foregoing reexamination of the process of diverticulum formation in the appendix has set forth some experimental evidence and

some morphologic facts, all of which have tended to support the muscular contraction hypothesis with which we started, and none of which have contradicted it. To recapitulate, it has been shown that there must be a weak point in the wall of the appendix which is probably due either to an especially broad vascular defect in the mesenteric or antimesenteric border filled with connective tissue, a condition found in most appendixes with diverticula, or to a scar in the muscularis, the result of a suppurative process, or to perforation during an acute attack, with protrusion of the mucosa and subsequent subsidence of the infection followed by regeneration of the mucosa within the former extramucosal abscess cavity.

It has been suggested that, in all forms of diverticula without exception, contraction of the circular and longitudinal smooth muscle coats is probably the chief active factor in driving the mucosa and submucosa through the weak point in the muscularis. In support of this, there is the morphologic evidence that, in all seven of the cases reported, the muscularis is above the average in thickness. In five of these, this is associated with more or less obstruction of the lumen proximally either by intraluminal mechanical means, complete obliteration, twists or angulations. In the other two, no obstruction could be demonstrated, but it was possibly present during life. Usually, this obstruction is accompanied by dilatation of the lumen, distal to it. There is also the condition of complete diversion of the lumen outside the muscularis into the diverticulum sac, which can be explained best by the muscular contraction hypothesis.

By experiment on dogs' appendixes, it has been demonstrated that operative muscular defects result immediately in protrusions of mucosa and submucosa accompanied by active contractions of the circular and longitudinal muscles, and that, when the muscles have lost their contractility, no protrusion will occur, if the lumen is empty. It has also been shown that moderate distention of the lumen will result in a similar protrusion, while extreme distention results in obliteration of the diverticulum.

From the foregoing data, the following attempt has been made to reconstruct the process of diverticulum formation. An appendix in which a diverticulum occurs must be thought of as a muscular tube above the average in thickness, and, because increase in structure connotes increase in function, capable of unusually powerful contraction, both longitudinally and transversely. It always contains submucosa, muscularis mucosae, mucosa and more or less material within the lumen. These different elements are relatively inert and should be thought of as the contents of the muscular tube, even though some of them are loosely attached to its inner surface. If such a muscular tube contracts, it becomes a potentially closed cavity, and there is exerted a

strong pressure on the contents, which may be considered as fluid, and so governed by the laws of hydrostatics. If there is a weak point in the muscular tube incapable of withstanding this transmitted force, it must yield, and the contents will protrude through the gap to a point where the driving and resisting forces become equalized. Depending on the balance between these two forces, the protruded elements may consist only of mucosa and submucosa immediately adjacent to the defect, or they may consist of the entire contents of the muscular tube in the segment containing the defect. In the former case, there will be a diverticulum consisting of a simple pouch lined with mucous membrane, in the latter, complete diversion of the lumen into the diverticulum sac.

#### REPORT OF CASES

##### APPENDICES WITH DIVERTICULA

CASE 1—July 3, 1922, a specimen was removed at necropsy by Dr B M Vance from a woman, aged 46, whose history was unknown (medical examiner's case)

*Gross Examination*—The specimens were the cecum, ascending colon, terminal ileum and appendix. The appendix was about 6 cm long and sinuously curved. Near its base a band extended from the parietal peritoneum to the mesentery of the appendix. Almost opposite this, another broad band extended from the terminal ileum and its mesentery to the appendix and its mesentery. These were probably congenital. The appendix varied in diameter from 5 mm, near the base, to 10 mm, just beyond the middle. When the cecum was distended, apparently no fluid passed into the appendix. The distal half of the appendix had a free mesentery, containing a considerable amount of fat. In this could be seen, buried in fat, two hemispheric bulgings, which were apparently continuous with the mesenteric border of the appendix.

A longitudinal section revealed that the lumen in the proximal part was patent, but measured only about 1 mm in diameter and contained a small amount of thick, slimy greenish material. At a distance of 37 cm from the cecal-appendiceal junction, the lumen came to an abrupt termination after being diverted to one side. A thin septum separated it from the terminal portion of the appendix, where the lumen was widely dilated up to 5 mm and filled with thick, white flocculent material. In this portion of the appendix, there were two defects in the muscularis of the mesenteric border, through the more proximal of which a protrusion of mucosa and submucosa had occurred for a distance of 4 mm. Through the more distal gap, not only had the mucosa and submucosa of the same side protruded, but also all the rest of the mucosa and submucosa of that region, so that the entire lumen had come to lie outside the appendix, within the sac of the diverticulum. From the diverticulum, the lumen passed back within the surrounding muscular coats once more in its course toward the tip, becoming markedly constricted as it did so. At the tip itself, there was a third defect in the muscularis through which the mucosa and submucosa passed, dilating up to 3 mm to form a terminal diverticulum, which was surrounded by the mesenteric fat at the tip. The muscular coat of the appendix throughout was thick, averaging from 1.5 to 2 mm. The vascular defects in the mesenteric border were for the most part slender white lines about 0.3 mm thick, one however measured 1 mm (Fig 1).



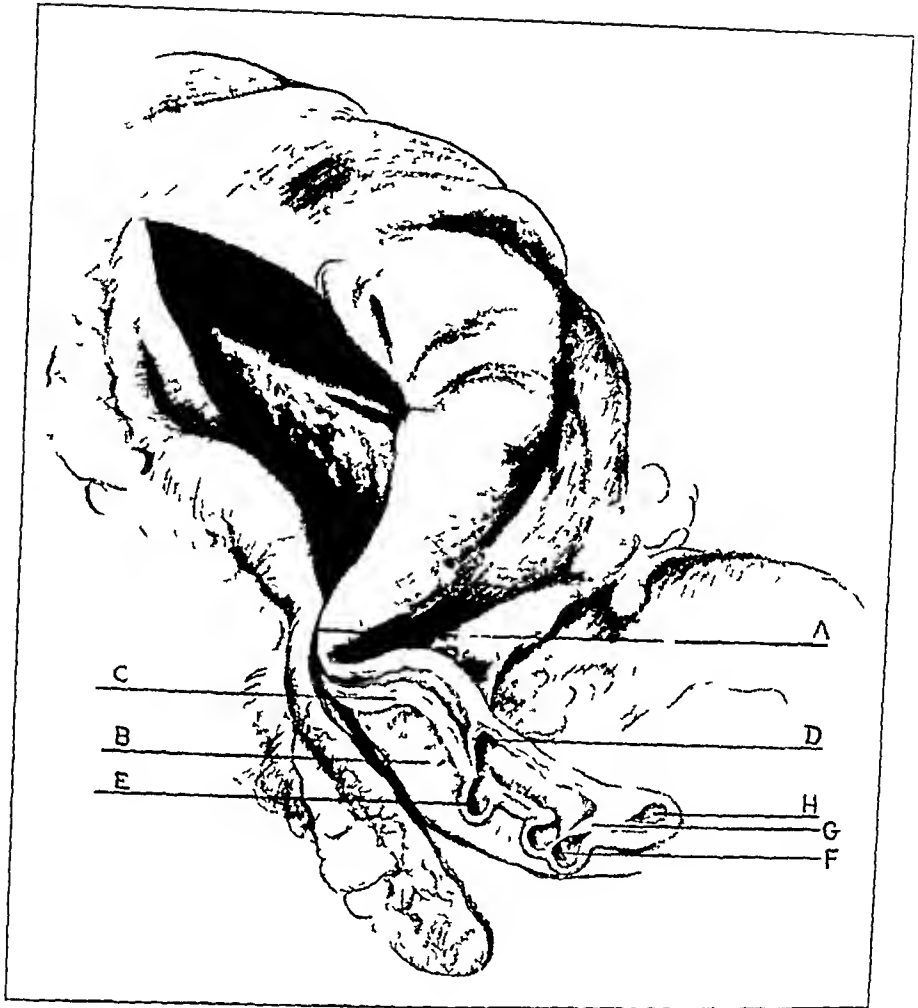


Fig 1 (Case 1) —Appearance of necropsy specimen from a woman, aged 46, with unknown history. The appendix has been bisected longitudinally. *A* is the junction of the appendix with the cecum, *B* the mesenteric border. The muscular coat *C* is easily distinguished, by its darker appearance, from the white appearing mucosa and submucosa. At *D*, a septum of mucosa and submucosa narrows the lumen and diverts it toward the mesenteric border, so that the proximal portion of the lumen is completely separated from the distal. Beyond this, the lumen is widely dilated, and the mucosa and submucosa pass through a defect in the mesenteric border forming the simple pouchlike diverticulum *E*. At *F* is another diverticulum with complete diversion of the lumen outside the muscular coats. The septum of submucosa and mucosa *G* appears complete in the plane of the section, but there was a small hole in it through which the continuity was maintained, indicated by the black marker in the diverticulum. *H* is a diverticulum at the tip.

*Microscopic Examination*—Sections from the terminal diverticulum revealed that the sac of submucosa and mucosa projected for only a short distance through the muscular defect. It was intimately adherent to the surrounding fat, and there were many dilated veins immediately about it. The mucous membrane lining the sac was thin and poorly supplied with glands, and the submucosa showed only an occasional small lymph follicle. Sections of the large diverticulum into which the lumen was diverted confirmed the gross findings in every way. The thin septum which passed from the wall of the appendix opposite the muscular defect, through and completely across the diverticulum to its apex, was composed of a central core of submucosa lined on both sides by mucosa. As in the diverticulum, at the tip the mucosa was thin and poorly supplied with glands, and the submucosa contained only an occasional lymph follicle. The subserosa was everywhere thick and well supplied with dilated blood vessels. The muscular coats appeared thick and intact, and were without evidence of previous inflammation.

*CASE 2—History*—F K, man, aged 30, married, a German fireman, suffered from cramps and vomiting for three days. He had had no previous similar attacks, and was never constipated. There was tenderness, and a mass was palpable in the cecal region. The temperature was 99.4 F. The white blood cells numbered 15,400, polymorphonuclears, 83 per cent.

*Operation* (Dr Joelson, supervised by Dr W B Parsons)—May 27, 1922. The appendix was acutely inflamed, laterad to the colon, extended up along the right side of the cecum, and was bound down by recent fibrinous adhesions. It was excised from the tip back, and the wound was drained. Recovery followed. June 12, 1922, there was a small granulating area still unhealed in the abdominal wound. Otherwise the patient was well.

*Gross Examination*—The specimen was about 12 cm long. It was slightly angulated at the junction of the proximal and middle thirds. The proximal third was about 9 mm in diameter. Beyond this, it plunged into an adherent swollen mass of fatty tissue, which was dusky red and covered with a flaky, fibrinous exudate. The diameter of this mass was 2.6 cm on the average (the appendix itself in this portion measured 1.7 cm in diameter), 1.2 cm from the base, there was a rounded, bulbous excrescence, slightly pedunculated and averaging 1 cm in all diameters, projecting from the mesenteric border. It was soft and reddened and had infiltrated fibrous tissue and fibrin adherent to its dome.

On longitudinal section, the appendix was found to be divided into three sharply defined zones. In the *proximal portion*, the lumen was a narrow slit less than 1 mm in diameter and apparently empty. It extended in a straight line for a distance of 1.5 cm, until it reached a point opposite the middle of the diverticulum, where it bent sharply at a right angle toward the mesenteric border and, accompanied by the mucosa and submucosa of both the mesenteric and antimesenteric borders passed through a broad defect in the thick muscularis. Here, it joined, by a mere potential slit, the *second portion* of the appendix. Beyond this slit, the lumen was abruptly dilated, forming the main cavity of the diverticulum. The lumen then passed back through the same defect in the muscularis, where it was somewhat narrowed and, turning again at a right angle, resumed its course along the center of the long axis of the appendix. This portion was 1 cm from the apex of the diverticulum to the center of the appendix and 2.5 cm along its long axis. It was filled in this portion with thick pale creamy material under slight tension. The muscularis in this portion had been torn away along the mesenteric border for a short distance probably by operative trauma. The second portion ended abruptly as

a blind pouch, the lumen at this point being completely separated from the distal portion. The *third portion* comprised a dilated lumen filled with bloody pus and lined with necrotic, hemorrhagic granulation tissue. There were two broad defects passing through the muscularis at the mesenteric border which seemed to be composed of reddened, congested fibrous tissue. The broadest was 12 mm. One similar, but much more slender, fibrous thread passed through the muscularis of the antimesenteric border. Surrounding the distal half was the tremendously thickened edematous fat of the adherent mesentery. On making further sections through the tip longitudinally, another diverticulum was revealed, with a neck passing through the muscularis about 1 mm broad, beyond which was a cavity 3 mm in diameter in the surrounding mesenteric fat. At its thickest part, the muscularis measured 15 mm in width. The width of the broadest vascular defect was 12 mm (Fig 2).

*Microscopic Examination*—The section through the large diverticulum, near the base, revealed that it was lined with flattened mucous membrane and that the thick, creamy material filling it was made up almost exclusively of

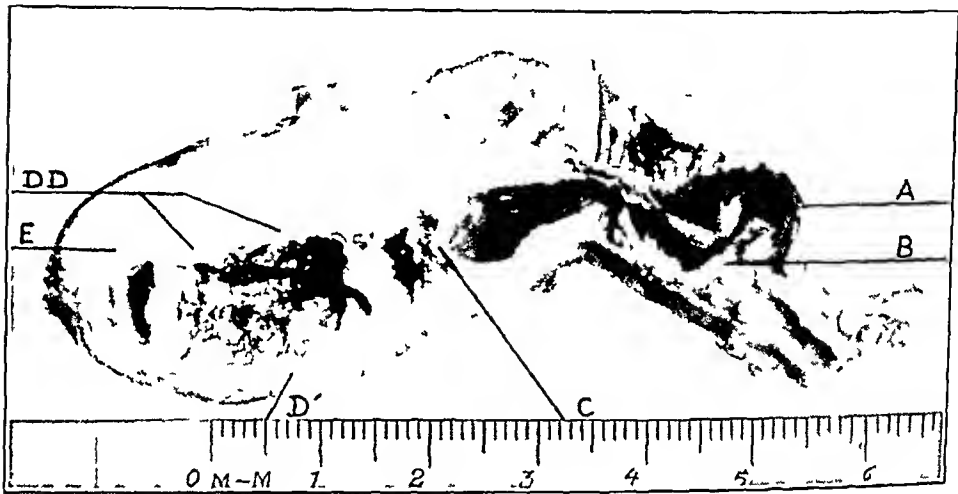


Fig 2 (Case 2)—Appearance of an acutely inflamed appendix from a man, 30 years old. There were no previous attacks. At A is shown a diverticulum in the mesenteric border near the base, with complete diversion of the lumen of the appendix into the diverticulum, because of the projection of the tongue of mucosa and submucosa B through the muscular defect (compare Fig 3). At C, the lumen is completely interrupted by a septum of connective tissue, beyond which there is partial necrosis of the mucosa coincident with the acute inflammation. D and D' are two vascular defects filled with connective tissue in the muscularis of the mesenteric border, D' is a similar defect in the muscularis of the antimesenteric border, E, region from which Figure 4 has been made.

leukocytes. The dilated central portion of the appendix which was continuous with this diverticulum was lined with a mucosa of similar type. The mucosa of the proximal portion was more normal in appearance. The neck of submucosa which extended from the antimesenteric side of the appendix through into the diverticulum was composed only of fibrous and fatty tissue, which was covered by the muscularis mucosae and mucous membrane. The diverticulum was covered exclusively by submucosa and muscularis mucosae, outside of which was adherent fatty tissue. A vessel of considerable size passed down

alongside the neck, which suggested that the diverticulum occurred in one of the normal vascular defects in the muscularis of the mesenteric border (Fig 3)

Sections from the tip of the appendix revealed that the mucosa was extensively destroyed by a suppurative process. Where it was preserved, it was represented by a single layer of columnar cells, with only a few short mucous glands scattered at intervals between them. At a point opposite the abscess,



Fig 3 (Case 2)—Appearance of microscopic section of diverticulum *A* shown in Figure 2—diversion of lumen surrounded by mucosa and submucosa through defect in muscular coats. The section is through a plane which shows the afferent and efferent sections of the lumen passing through the vascular defect, but does not show its continuity toward the cecum at *A*, nor toward the tip at *B*. This continuity is apparent in Figure 2

there was a defect in the muscularis and through this, mucous membrane extended to a point almost opposite the external coat. Here it ceased and the rest of the cavity was lined with granulation tissue and filled with a mass of leukocytes mixed with mucus and mononuclear cells (Fig 4)

The condition in the tip suggested that a mucocoele was probably in the course of formation in the distal isolated portion with a diverticulum at its tip. An infection involved the tip, causing a perforation of the diverticulum, which had resulted in abscess formation in the mesentery. The central portion had probably been involved secondarily in the acute inflammatory reaction, causing an empyema involving this portion and its extension into the proximal diverticulum. The small proximal portion attached to the base had practically escaped involvement at this stage of the infection.

**CASE 3—History**—L W, a colored woman, aged 20, single, an American, who was doing maid service, had suffered pain in the right lower quadrant for the past two weeks, which had grown steadily worse and was increased by urination. There was no nausea, but she had vomited twice. Two similar attacks had occurred, one and two and one-half years ago, with fever which lasted from four to six weeks. In the past she had four attacks of pain, swelling and redness of the left ankle and shoulder. She was usually constipated. Promiscuous intercourse was admitted.

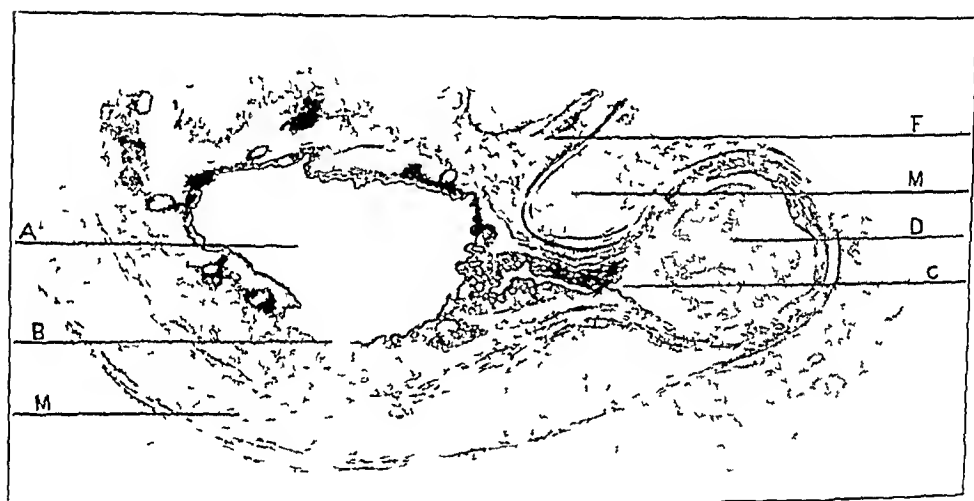


Fig 4 (Case 2)—Drawing of microscopic slide of section made through tip of appendix at *E* in Figure 2, but at a deeper plane. The lumen of the appendix is shown at *A*, surrounded by inflamed mucosa which has been destroyed at *B*. At *C* is the opening of a mucous membrane lined tract which leads through a defect in the muscular coats *MM*, into an extra-muscular cavity *D*, lined with granulation tissue and filled with mucus and pus. At *F* is a connective tissue filled vascular defect passing from the mesenteric lumen through the muscular coats to the submucosa.

**Examination**—There was marked tenderness low down in the right lower quadrant and slight tenderness in the left lower quadrant. The cervix was large, soft and irregular. There was intense pain when the cervix was moved. There was a tender mass in the right fornix and slight tenderness in the left fornix. The patient was observed in the hospital for eleven days, during which time she improved greatly. The temperature ranged from 101.4 to 98 F. The white blood cells numbered 8,100, polymorphonuclears were 81 per cent, hemoglobin, 70, the red blood cells numbered 4,600,000. The Wassermann reaction was negative.

*Operation* (Dr Joelson, supervised by Dr J Greenough) —March 13, 1922 Right salpingo-oophorectomy, left salpingectomy, myomectomy of small uterine fibromyoma and appendectomy were performed The appendix was retrocecal and entirely retroperitoneal Uneventful recovery ensued May 13, 1922, the wounds were fully healed, and the patient felt relieved of symptoms

*Gross Examination* —The specimen was an appendix 6 cm long and varying from 5 to 8 mm in diameter The surface was dull and roughened The superficial vessels were injected There were several small firm white nodules on the mesenteric and antimesenteric borders, averaging about 2 mm in diameter On the mesenteric border near the tip, there was a much larger one, projecting 4 mm from the surface and measuring 5 mm in diameter On longitudinal section, the lumen of the appendix was found to be patent to within 7 mm of the tip, from 3 to 4 mm in diameter, and filled with inspissated fecal material The wall of the appendix averaged 2 mm in thickness, of which the muscularis occupied 1 mm One fibrous band was seen passing through the muscularis in the mesenteric border, which was 0.8 mm in diameter The terminal 7 mm of the appendix seemed to show first an obliteration of the mucosa and its replacement by fibrous tissue, beyond this the lumen was a mere potential space surrounded by a small amount of mucous membrane It seemed to pass out into the large nodule projecting from the mesenteric border (A more detailed description of this appendix cannot be given for it was unfortunately mislaid after this preliminary examination had been made) With the appendix were a fibromyoma of the uterus, two chronically inflamed tubes and a cystic ovary

*Microscopic Examination* —Sections from the tip of the appendix revealed a diverticulum formed by the extension of the submucosa and mucosa through a defect in the muscular layers On one side of the diverticulum a slender strand of the inner circular muscle had been carried through the gap with the submucosa and extended almost to the highest portion of the dome of the diverticulum There were two distinct lumina in the diverticulum, lying side by side as it passed through the muscularis, each lined with mucosa and submucosa, which join in the extramuscular sac A good sized vein lay alongside the neck of the diverticulum as it passed through the muscularis A section taken from one of the smaller nodules along the mesenteric border described in the gross presented a mass composed of connective tissue surrounding a number of relatively large thick walled veins passing through a gap in the muscularis and widening out to form a thicker rounded mass outside the muscularis, in this way simulating a diverticulum, although no mucous membrane appeared in it (This is an example of the false diverticulum described by Seelig<sup>25</sup>) None of the sections presented any signs of acute inflammation

CASE 4—*History* —E W, man, aged 54, a widower, American, had suffered for thirty-six hours from generalized pain in the abdomen and vomiting He had had no previous similar attacks but had had vague gastric disturbances and cramps occasionally in the past There were tenderness and muscular spasm about the umbilicus and in the mesial portions of both lower quadrants The temperature was 100.6 F The white blood cells numbered 21,000, the polymorphonuclears were 93 per cent

*Operation* (Dr Greenough) —Jan 27, 1922 Appendectomy with drainage was carried out The appendix lay behind the ileocolic junction in a region

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25 Seelig False Diverticula of the Vermiform Appendix, Ann Surg 44 78 1906

of localized peritonitis. A stormy postoperative course was attended by a pulmonary embolus with infarction of the lung. June 6, 1922, there was bulging of the abdominal wound, but the condition was otherwise good.

*Gross Description*—The specimen was 4 cm in length, 1.3 cm in diameter near the base and 1 cm in diameter at the tip. It was reddened and edematous throughout, but more markedly so in the distal half, which was covered with a greenish-yellow fibrinous exudate. The mesenterium was also swollen and edematous, with a broad attachment. It was covered with a fibrinous exudate throughout its length. On longitudinal section, it could be seen that the thickening in the proximal half was due to a tremendous thickening of the submucosa. The muscular coat was 2 mm thick. Along the mesenteric border, there were eight vascular defects from 1 to 15 mm in thickness, passing through it at right angles to the lumen. On the antimesenteric border, the vascular defects were barely visible. The lumen for a distance of 2.3 cm was small but patent and passed with slight deviations nearly through the center of the appendix, then it made a right angled turn and, accompanied by the mucosa and submucosa, passed through the muscular coat to form a dilated sac



Fig 5 (Case 4)—Appearance of acutely inflamed appendix from a man of 54, who had had no previous attacks. At the left is the external appearance of the appendix, with the thickened mass of the mesentery above, with fibrin adherent to it. To the right is a longitudinal section showing the single diverticulum in the mesenteric border with complete diversion of the appendix lumen into it. The thick muscular coats appear as a broad dark band, interrupted along the mesenteric border by the diverticulum and by seven sharply contrasted connective tissue filled vascular defects.

5 mm in diameter between the leaves of the mesenterium. It then proceeded directly back toward the center of the appendix, paralleling its former course outward, and passing through the same muscular defect. Having reached the center of the appendix, it proceeded on its course to the tip. The muscular defect through which the two arms of the lumen passed measured 4.5 mm in width. We thus had a complete diversion of the lumen through the muscularis into the mesenterium. At one point, the mucosa lining the diverticulum was defective, indicating a pin point perforation into the mesentery (Fig 5).

*Microscopic Examination*—Longitudinal sections revealed that the diverticulum in the mesentery had a lumen 5 mm in diameter, lined with intact mucosa surrounded by submucosa and the thickened edematous, inflamed mesentery. Only one of the mucosal tubes connecting it with the site of the original appendix lumen was shown in these slides. This was also lined with

intact mucosa as it passed through the broad defect in the muscularis. Several other broad defects in the muscularis were seen, through which passed blood and lymphatic vessels and dense connective tissue. Surprisingly little evidence of the acute inflammatory reaction appeared in the section except in the form of a fibrinopurulent exudate on the serosa and fibroblastic reaction in the mesentery, together with a moderate edema and dilation of lymphatic vessels (Fig 6).

CASE 5—*History*—J F D, man, aged 21, single, American, a clerk, suffered sudden sharp cramplike pains in the abdomen which were not relieved by any measures taken. The bowels moved, and he vomited once. He had had six similar attacks during the past year. He was usually constipated. The tempera-

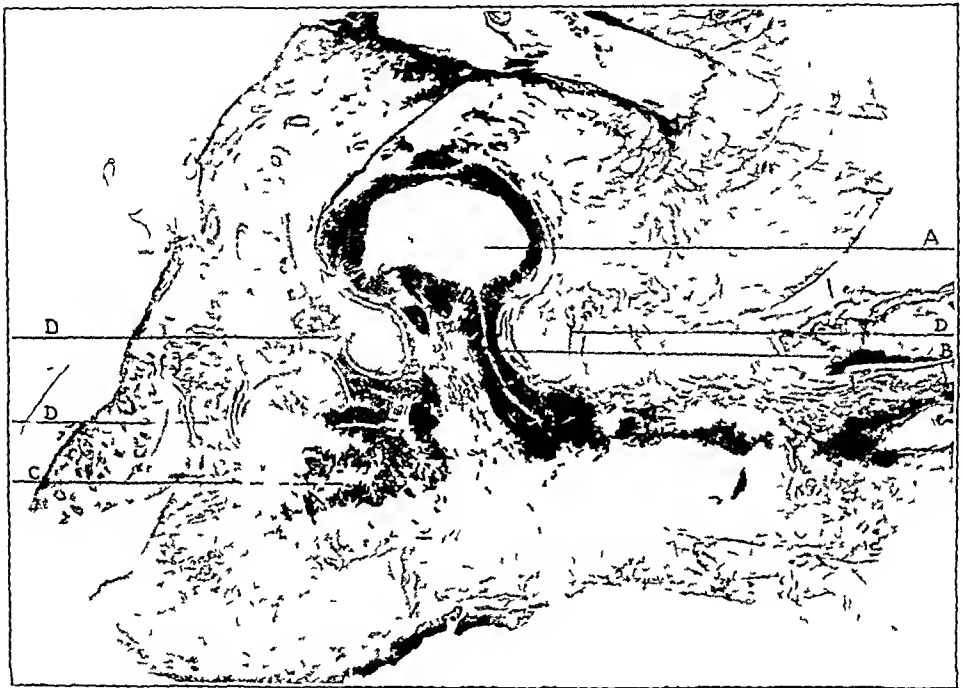


Fig 6 (Case 4)—Photomicrograph of the appendix shown in Figure 5. The diverticulum lined with mucosa and submucosa in the mesenteric fat is shown at *A*. The afferent portion of the lumen leading from the cecal end of the appendix to the diverticulum sac is shown at *B*. The continuity of the diverticulum with the lumen of the appendix at the tip *C* is not shown in this section but is clear in Figure 5. *DDD* are four of the broad defects in the mesenteric border of the muscularis filled with blood vessels and connective tissue. The ball-like expansions of these outside the muscular coats (so-called false diverticula) are well shown.

ture was 100.6 F. The white blood cells numbered 17,600, polymorphonuclears 90 per cent. Tenderness was noted on both sides of the midline below the umbilicus. There was rectal tenderness anteriorly and marked distention of the colon.

*Operation* (Dr H A Murray, supervised by Dr W G Penfield)—Jan 9, 1922. The appendix was retrocecal, apparently perforated near the tip, swollen, reddened and covered with fibrin. A quantity of free, gray purulent



fluid was found in the peritoneum, which grew *B. acidilactici*. Appendectomy was performed, with drainage. The wound healed slowly, but convalescence was otherwise smooth.

July 18, 1922. The scar had a slight tendency to bulge, otherwise the patient was well.

**Gross Examination**—The specimen was an appendix about 5 cm long and 0.8 cm in diameter. It was slightly curved, reddened and edematous, and the distal half was dusky red and covered with a thick, flaky fibrinous exudate. The mesentery was thickened and attached along the convex border. No diverticula were visible externally, nor was there external evidence of perforation.

On longitudinal section of the organ, it was apparent that at the base for a distance of 5 mm the lumen of the appendix was completely occluded and replaced by fibrous tissue. Distal to this the lumen was widely dilated and lined with a smooth layer of mucous membrane. It contained cloudy fluid. It was at once apparent that there were three complete diverticula along the mesenteric border in the distal half. Two of these measured about 4 mm in diameter and consisted apparently of protrusions of mucosa and submucosa.



Fig 7 (Case 5)—Appearance of the acutely inflamed appendix of a man, aged 21, who had had six preceding acute attacks. To the left is the external appearance, showing the tip covered with fibrin and the mesentery attached along the convex border, to the right a longitudinal section, showing complete obliteration of the lumen at the base, *A*, beyond which it is widely dilated. *B'*, *B''* and *B'* are three diverticula in the mesenteric border. *C* is a muscular defect in the mesenteric border, and *D*, a muscular defect in the antimesenteric border. Between *B'* and *B* is what appears to be an incomplete diverticulum. This is incorrectly drawn, as it is a defect similar to *D*.

through defects in the muscularis, which were about 2 mm in diameter. The most distal diverticulum near the tip was much larger when it reached the mesentery, spreading out over an area nearly 1 cm in length. It was filled with semigelatinous, mucoid material and there was a perforation through one end into the mesenteric fat. It was noticeable that there were, in addition to the complete diverticula, two defects in the muscularis along the mesenteric border and one along the antimesenteric border, all of which were filled with dense, white connective tissue. The defect on the antimesenteric border was capped with a small ball of dense white tissue in the subserosa. No lumen or mucosa appeared to be present in these three areas. The muscularis measured about 2 mm in thickness. The broadest point was 22 mm in thickness. The connective tissue filled defects averaged 0.5 mm in diameter (Fig 7).

*Microscopic Examination*—A section taken near the tip revealed that the largest diverticulum was a protrusion of submucosa, muscularis mucosae and mucosa through a large defect in the muscularis, into the tissue between the leaves of the mesentery. It had spread out considerably in this situation and at its proximal end had a defect in its lining mucous membrane which communicated directly with a mass of mucus lying free in the tissues. This mucus was mixed with round cells and leukocytes. In the surrounding tissues, there was edema, congestion of vessels and cellular infiltration. On the serous surface was adherent an exudate of fibrin and leukocytes (Fig 8). The other two diverticula were of the usual type. There were also defects in the mesenteric border of the muscularis, filled with connective tissue which surrounded thick walled veins. The lack of signs of inflammatory reaction in the appendix itself made one suspect that the infection started possibly in the mucocele which came from the diverticulum at the tip of the appendix.

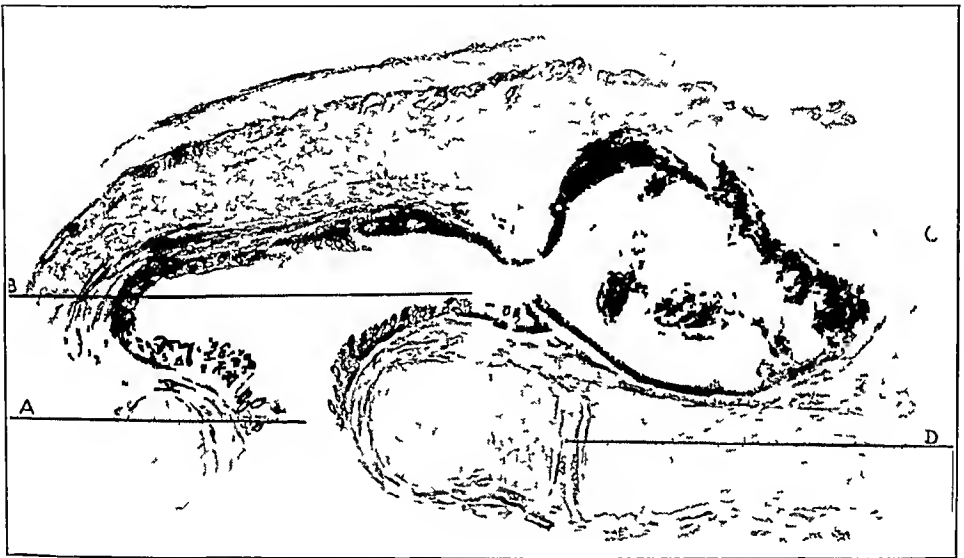


Fig 8 (Case 5)—Drawing made from the microscopic section of diverticulum B", Figure 7. At A is shown the neck of the diverticulum leading to the extra muscular cavity which is lined with mucous membrane except at B, where it stops at the small opening shown in the illustration. This leads into an accessory cavity C, which is lined with the connective tissue of the mesentery and contains mucus and leukocytes. The mucous membrane lining the lumen of the appendix was torn away in making the section. Here, we have a diverticulum with an infected mucocele leading off from it. D is a vascular defect.

*CASE 6—History*—M. F. C., woman, aged 28, single, American, a book-keeper, came to the hospital to have the appendix removed because of a recent acute attack of appendicitis.

*Examination*—On admission, tenderness was elicited on deep palpation in the right lower quadrant. All other signs were negative. The temperature was 99 F. The white blood cells numbered 7,100, polymorphonuclears, 66 per cent.

*Operation* (Dr F. B. St. John)—July 23, 1921. Appendectomy was performed. The appendix was found in the pelvis adherent to the surrounding

structures by recently formed soft adhesions. Three nodules were noted along the antimesenteric border and one at the tip. The patient made a good recovery.

*Gross Examination*—The specimen measured 65 cm in length and 1 cm in diameter in the distal half. A large mass of mesenteric fat was attached distally. It was pink and smooth, except in a few scattered areas from which adhesions had been torn. At the tip was a firm rounded pale mass, 7 mm in diameter. Three similar rounded projections, smaller in size, were seen on the antimesenteric border in the distal half. On longitudinal section, it was seen that the appendix was somewhat irregularly curved, with its concavity toward the mesentery. The lumen appeared to be patent throughout, varying from 2 to 3 mm in diameter. White lines representing vascular defects filled with connective tissue could be seen in both the mesenteric and the antimesenteric

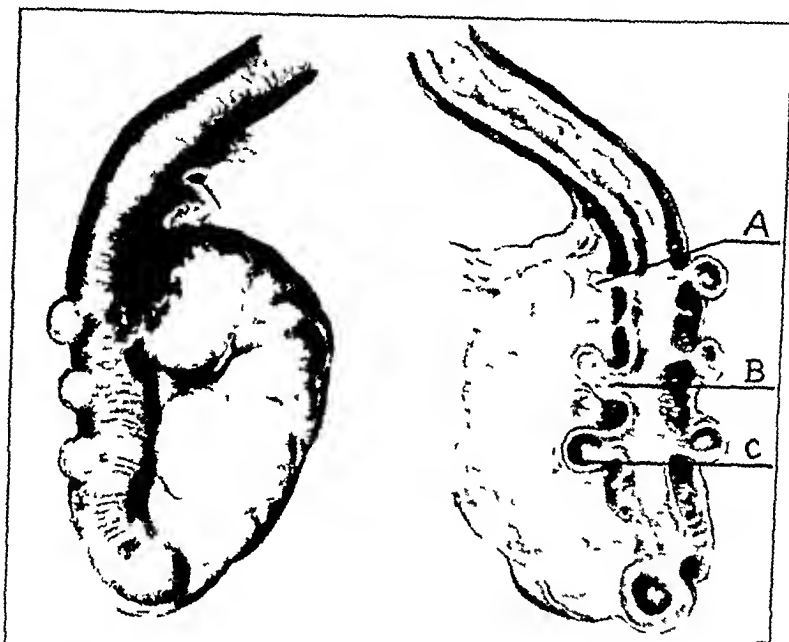


Fig 9 (Case 6)—Appearance of appendix removed from a woman of 28 in an interval following an acute attack. To the left is the external appearance of the appendix showing the three nodules on the antimesenteric border, one at the tip and the large mass of fat in the mesenteric lumen, to the right, a longitudinal section showing these four diverticula and three others in the mesenteric border, at A, B and C. It will be noted that the lumen is patent throughout and remains within the muscular coats, although diverticulum B has apparently two cavities. (For an explanation of this, compare the gross description of Case 6.)

borders. The broadest one was in the former, measuring 1 mm in width. It was at once apparent that there were seven diverticula in the appendix—three in the mesenteric and three in the antimesenteric border, and one at the tip, which was the largest. All of these seemed to be simple protrusions of the mucosa and submucosa through the muscularis, which averaged 2.7 mm in thickness, except the middle one on the mesenteric side, which was a more complicated affair. There seemed to be a fold or septum of mucosa and submucosa in the neck of the diverticulum as it passed through the muscularis so that in one half of the cut section it appeared as if there were two lumina,

while in the opposite half there appeared to be only one. Outside the muscularis, the diverticulum appeared to have two distinct mucosa lined cavities (Fig 9). This seemed to be an intermediate stage between the usual simple unilateral protrusion of the mucous membrane and the complete deviation of the lumen into the diverticulum sac, illustrated in the first four cases.

*Microscopic Examination*—Longitudinal sections of the appendix taken through the middle revealed three of the diverticula, two on the mesenteric and one on the antimesenteric border. It revealed the tremendously thick mus-

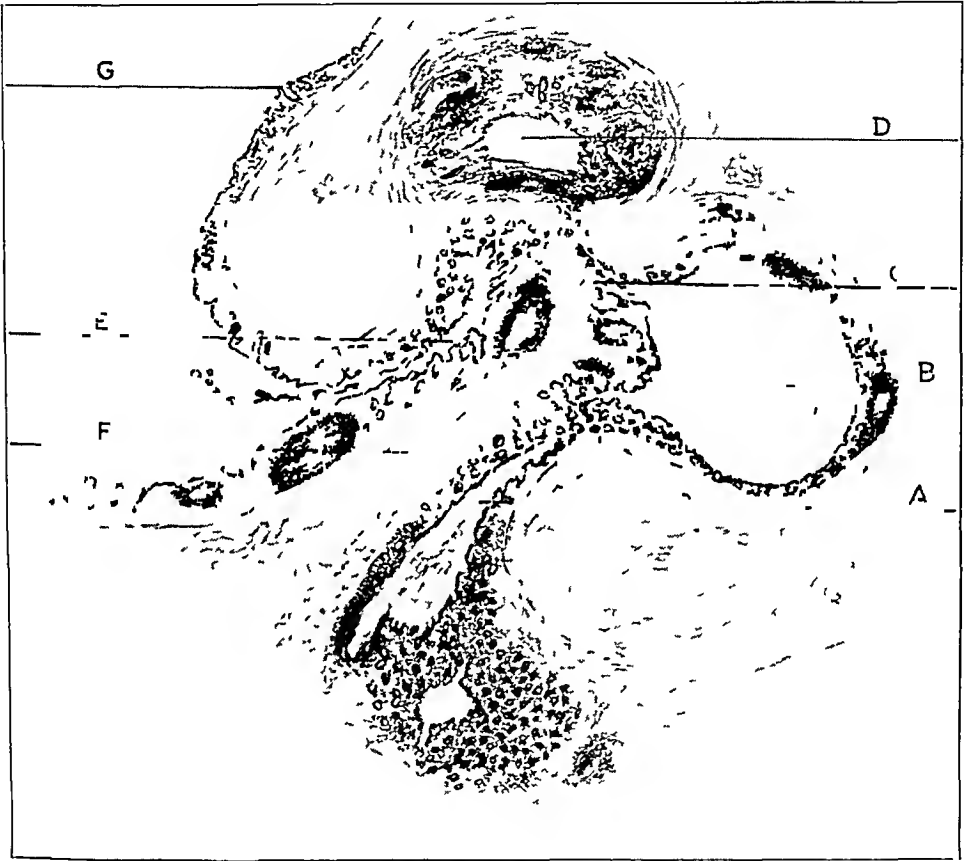


Fig 10 (Case 6)—Appearance of microscopic section of diverticulum, *B*, shown in Figure 9. The section was made from the half of the appendix opposite that illustrated in Figure 9. In this illustration, the lumen, *A*, passes through the muscularis from the proximal portion of the appendix to an extramucosal cavity, *B*. This, in turn, communicates with a second adjacent cavity, *D*, via *C*, and the lumen then passes back within the muscular coats at *E*. *G* indicates a portion of diverticulum *C*, Figure 9. Although the tongue of submucosa, *F*, apparently occludes the lumen, this condition obtains only in this half of the appendix and not in the opposite half, illustrated in Figure 9.

cular coat which had a minimum amount of connective tissue in it. Two of the diverticula were simple protrusions of mucosa and submucosa through muscular defects. In the other one, the lumen of the appendix appeared to be completely diverted, passing through the muscular defect into two mucosa lined cavities in the mesentery which were connected by a narrow passage,

and then passing back again through the muscular defect. These bulbous enlargements were filled with cellular and amorphous debris. In the surrounding fat, there were a few round cells and leukocytes. There was no evidence of acute inflammation (Fig 10). In places where vascular defects without diverticula passed through the muscularis, the density of the connective tissue surrounding the veins and lymphatics was demonstrated. In one instance, a rounded mass of this dense connective tissue with a mass of tortuous vessels included in it could be seen capping the muscular defect. This reached a diameter of 4 mm and was an example of the false diverticulum described by Seelig.<sup>22</sup> The serosa was thickened and edematous, and presented many dilated capillaries and lymphatics.



Fig 11 (Case 7) —Photomicrograph of appendix from a man of 20, removed during an acute attack, with a history of four or five preceding attacks. The section shows the tip of the appendix with a diverticulum, *A*, lined with mucosa passing through a defect in the muscularis. At *B* and *C* can be seen fragmented smooth muscle bundles, which have apparently been carried out for a short distance with the protrusion of the mucosa.

**CASE 7—History**—J. R., man, aged 20, single, American, a farmer, had had pain and soreness in the right lower quadrant for two days. The bowels had not moved for two days. Four or five mild attacks of similar nature had occurred in the past six months. The patient was not usually constipated. There was tenderness in the right abdomen, most marked in the right lower quadrant, with rigidity. There was rectal tenderness high on the right. The temperature was 102° F. The white blood cells numbered 16,000, polymorphonuclears, 85 per cent.

*Operation* (Dr Jameson)—April 18, 1915 Appendectomy with drainage was performed. The cecum was undescended and of the infantile type. The appendix was retrocecal, and an abscess surrounded the tip, which was up under the liver. There was cloudy fluid in the pelvis. The patient made a good recovery. When last seen, twenty-one months after operation, he was perfectly well.

*Gross Examination*—(As the specimen has been lost, the following is a copy of the examination made in 1915.) The specimen was 8 cm in length. It was sharply angulated at the junction of the proximal 3 cm with the distal 5 cm. The proximal portion was 1 cm in diameter and, after making the right angled turn, it disappeared into a mass of edematous infiltrated fat. In the distal portion, the wall was edematous and infiltrated. The mucosa appeared gangrenous, the lumen was patent but was filled with purulent and fecal material, 1 cm from the tip, there was a diverticulum of the lumen into the surrounding fat. It projected for a distance of 5 mm and was somewhat bulbous, the broadest part measuring 5 mm in diameter. The muscularis averaged about 2 mm in thickness. As the appendix had not apparently been cut in a plane passing through the mesenteric and antimesenteric borders, no vascular defects could be seen.

*Microscopic Examination*—Section made through the tip of the appendix revealed that the mucous membrane in this portion was intact and, with the muscularis mucosae and submucosa, passed out through a defect in the muscularis for a short distance, into the surrounding fat. All the coats in this region were edematous and were infiltrated with leukocytes and round cells. This was most marked in the extramuscular fat, where, in addition, all the vessels were engorged and there had been considerable proliferation of fibroblasts. It was interesting to note that a few bundles from both the longitudinal and the circular muscle coats had been carried outward along the side of the diverticulum nearly to its apex (Fig 11). Aschoff<sup>23</sup> quotes von Brunn<sup>24</sup> to the effect that this phenomenon is seen in connection with diverticula which have followed inflammatory damage, and serves to distinguish them from the other type. The evidence is all in favor of this being an example of a diverticulum resulting from a former perforation of the appendix and protrusion of the mucosa, with subsequent repair and regeneration of the mucosa within the extramuscular tissue.

#### PERFORATED APPENDICES

CASE 8—*History*—J. Z., man, aged 31, married, Hungarian, a janitor, had an acute attack of abdominal pain, with constipation, lasting two days, finally localized in the right lower quadrant. There had been no previous attacks. The patient had never been constipated before. There were marked pain and tenderness in the right lower quadrant and right flank. Rectal examination was negative. The temperature was 101.8 F. The white blood cells numbered 22,000, polymorphonuclears, 92 per cent.

*Operation* (Dr F. B. St. John)—Jan 16 1916 Appendectomy was performed with drainage. The appendix was retrocecal and had ruptured. There was a localized abscess about it, which contained a concretion. Culture of pus showed *B. faecalis alcaligenus* and streptococcus. Two years after operation the patient was perfectly well.

<sup>26</sup> Von Brunn. Ueber Divertikelbildung bei Appendicitis. Beitr. z. klin. Chir. 46: 67, 1905.

*Gross Examination*—The specimen was 4 cm long. The proximal half was swollen, reddened, and covered with a fibrinous exudate. In the antimesenteric border, there was an area of perforation nearly 1 cm in length. The mucosa in this area appeared to be everted and was covered with a thick, greenish yellow exudate. The distal half of the appendix was swollen and reddened, but was not nearly so much affected as the proximal part. With the appendix was a fecal concretion which was rounded and firm, and measured about 1 cm in diameter.

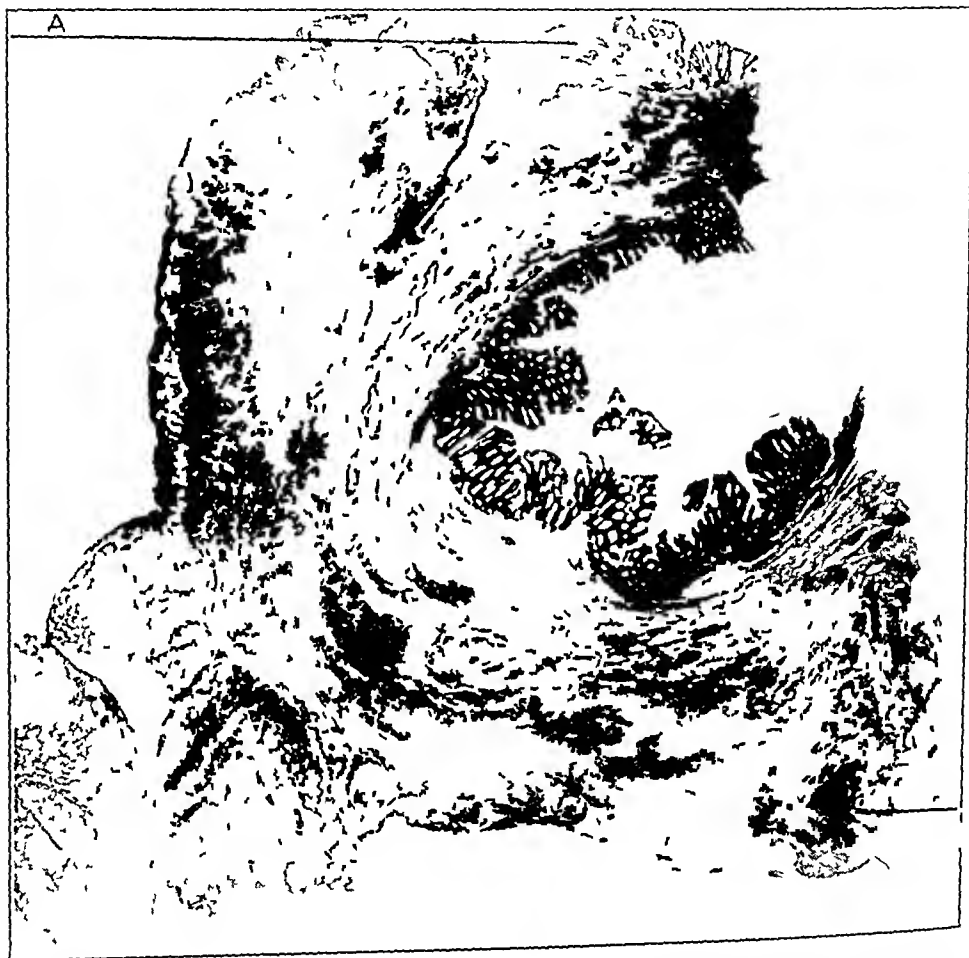


Fig 12 (Case 8) —Photomicrograph of a cross section through a perforation of an acutely inflamed appendix. The broad defect involving one third of the circumference can be plainly seen, and at *A* and *A'* the extent of the eversion of the protruded mucous membrane, which at *A'* is practically continuous with the serosa.

*Microscopic Examination*—The section was made transversely through the perforation. All of the coats were much distended with edema and massively infiltrated with leukocytes. The defect in the lumen was in the antimesenteric border and occupied about one third of its circumference. The muscularis had retracted so that it occupied only about one half of the circumference of the appendix. The mucosa and submucosa projected out beyond the muscularis and were everted so that on one side the mucosa reached to the serosa, while

on the other side it extended to a point opposite the middle of the muscularis. The mucosa within the appendix was relatively intact, but the protruded portion was denuded of surface epithelium and was represented by edematous granulation tissue, in which the tubular glands appeared. There was no lymphoid tissue in any part of the submucosa (Fig 12).

**CASE 9—History**—S. A., woman, aged 23, single, Spanish, a dressmaker, had an attack beginning about thirty hours before operation, of nausea, vomiting and generalized abdominal pain which later became localized in the right lower quadrant. Two years before she had had an attack of pain in the right lower quadrant, accompanied by fever and vomiting which lasted eight days and during which a mass could be felt in the right lower quadrant. She was treated with morphin and ice bags.

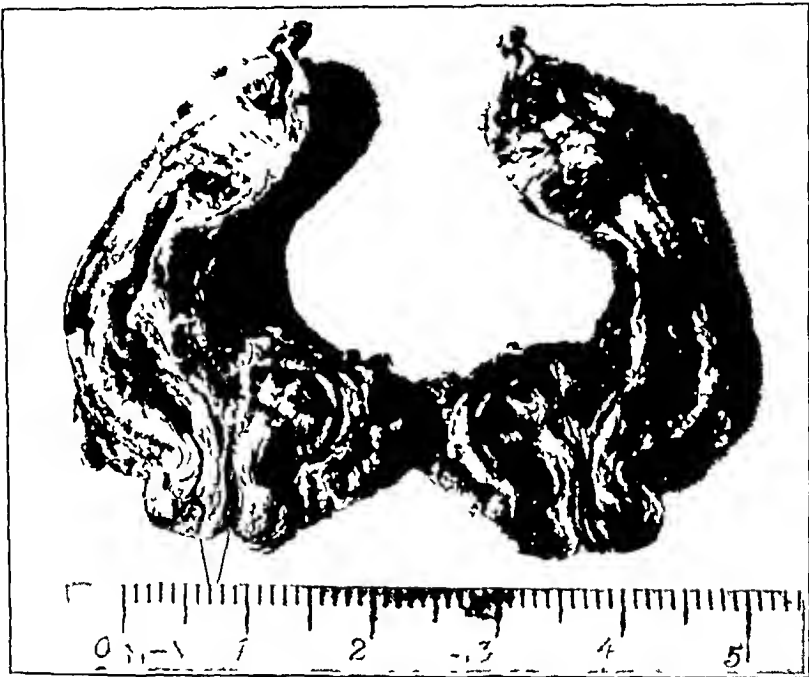


Fig 13 (Case 9)—Appearance of appendix removed from a woman of 23 during an acute attack, with one previous acute attack two years before. The appendix has been divided longitudinally. The appendix has perforated, with protrusion of the entire lumen. The two wire markers have been passed into the separated portions. The entire nodular area surrounding these two wires on the external surface of the appendix is covered with mucous membrane.

**Examination**—On examination, at the Presbyterian Hospital, there were rigidity and tenderness over the lower right rectus, extending out into the flank. No masses were felt. The temperature was 99 F. The white blood cells numbered 12,000, polymorphonuclears, 81 per cent.

**Operation** (Dr J. Greenough)—Aug 8, 1921. Appendectomy was performed, with drainage. The appendix was buried in dense adhesions and was incorporated in the wall of the cecum, starting posteriorly and curving forward along the lateral aspect. There was an old perforation near the tip, from which the mucosa pouted. No holes could be found in the cecal wall. Pus escaped from



the appendix during removal. Following operation, the patient had a secondary hemorrhage in the wound, suppurating parotid sialadenitis, bed sores on the back and heels, and cecal fistula. Jan 17, 1922, the cecal fistula was closed by operation. March 22, incision and drainage of a subhepatic abscess was carried out. June 10, 1922, all wounds had healed, the patient felt well and was gaining weight.

*Gross Examination*—The specimen was 55 cm long and markedly curved throughout its length. It was swollen, reddened, and covered with the shaggy remnants of recently separated adhesions. Near the tip in the antimesenteric border was a rounded, elevated area covered with reddened mucous membrane about 1.3 cm in diameter and raised 5 mm above the surface of the appendix. In this, there were two pin point openings, one of which was the mouth of a tract leading toward the tip of the appendix, while the other was the external opening of a tract communicating with the lumen of the appendix toward the base. On longitudinal section of the appendix, these two mucous membrane lined tracts could be seen passing through a defect in the muscularis 6 mm wide. Thus, there was a complete diversion of the lumen of the appendix into the extra-appendiceal abscess cavity. The muscularis near the tip measured about 1.5 mm in thickness. Several broad white bands in the mesenteric border of the appendix represented the vascular defects. The broadest of these was 1 mm wide (Fig 13).

*Microscopic Examination*—We were not successful in getting a section which included both tracts in the same slide. However, they showed the mucosa and submucosa passing outside of and well beyond the muscularis and then turning outward and downward until it met the serous coat at a considerable distance from the point at which it passed through the muscular defect. It was well formed, and, in its extra-appendiceal portion, the cells making up the glands were mostly of the goblet variety. The coats of the appendix were somewhat edematous, but presented only a very moderate infiltration with leukocytes and round cells.

#### PROTOCOLS OF EXPERIMENTS

*Experiment 1*—A young adult female mongrel of the hound type, weight about 25 pounds (11.4 kg), was operated on, Oct 27, 1921, under ether anesthesia, the appendix and cecum being delivered into the upper part of a right rectus incision. The appendix had a separate mesentery and, except for the tip, was bound down closely to the cecum. It emptied easily into the cecum and refilled almost immediately as soon as the pressure was removed. An area 6 by 8 mm near the tip was denuded of serosa, subserosa and muscularis by sharp dissection with the knife. At once, the submucosa and mucosa bulged through the defect, forming a dome shaped swelling 4 mm in height. At the same time, it was noted that the appendix contracted both in diameter and in length, and its wall became very hard. After some seconds, this muscular spasm was relaxed, and, coincidently with the softening of the appendix wall and the increase in its dimensions, the diverticulum appeared slightly less prominent and its walls slightly less distended. It never disappeared. A ligature, together with an attached piece of omentum, was now tied about the middle of the appendix, passing through a hole in the mesenterium, thus constricted the appendix considerably, and it was hoped that, with the formation of scar tissue, a permanent obstruction would be obtained. The abdominal wound was then closed.

The dog, which had been suffering before from distemper, died of that disease, Nov 18, 1921, twenty-two days after the operation. At necropsy, a

moderate number of adhesions of omentum to the appendix were found. The terminal ileum, cecum, ascending colon and appendix were removed from the body en masse and distended with liquor formaldehydi (formalin) before being studied.

*Gross Examination*—The diverticulum was now about 8 mm in diameter and passed through a muscular defect 5 mm in diameter. It was, therefore, slightly larger than before. Where the omentum and silk ligature were tied

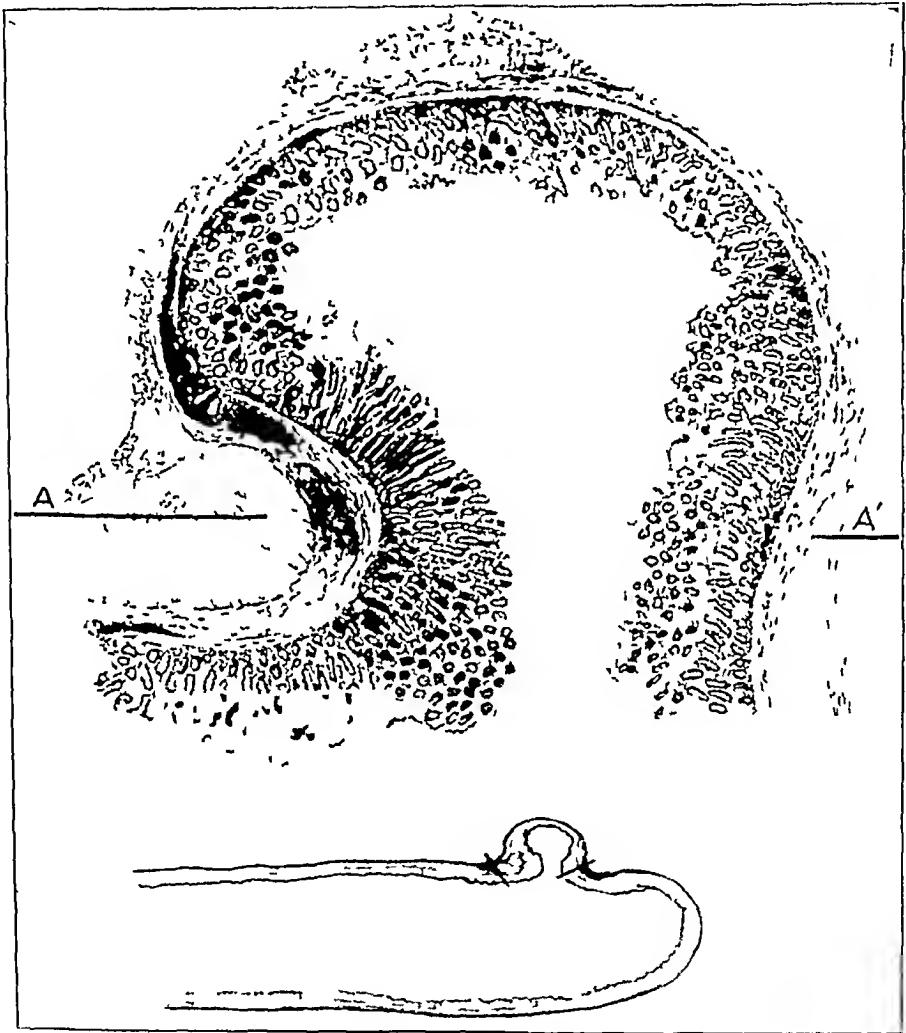


Fig 14 (Experiment 1)—Appearance of distal portion of dog's appendix showing experimentally produced diverticulum twenty-two days after the muscular defect was made. Above is a drawing made from a microscopic section of the area included between the heavy lines in the sketch. It shows at *A* and *A'* the ends of muscle coats with the protruding mucosa and submucosa passing out to form an extra muscular pouch. Attached to the apex of the diverticulum is a torii adhesion.

about the appendix, the lumen was decreased to one half in its diameter, but there was no obstruction.

*Microscopic Examination*—A section through this diverticulum was identical with that of "acquired" diverticula in the human appendix. It showed a

protrusion of mucosa, muscularis mucosae and submucosa through a muscular defect. Attached to the exposed submucosa was some adherent omentum (Fig 14)

*Experiment 2*—A small male mongrel was operated on Dec 30, 1921, under ether anesthesia, the technic being a repetition of that employed in Experiment 1. In this case, two defects were made—one, 5 mm square, by excision of muscular coats, the other, by a simple incision 1 cm long down to the submucosa. In this case, there was a bulging of the submucosa and mucosa through the defects when the appendix contracted, but it was not marked and almost disappeared with relaxation. A thick doubled silk ligature was tied very tightly about the middle of the appendix, so that the lumen was obstructed.

The dog underwent another experiment performed on his spleen during the same operation, and died two hours later, with shock and mesenteric thrombosis. At necropsy, the appendix was found covered with fibrinous exudate and a small amount of blood. It was soft and flaccid, and, although there was a slight bulge of mucosa and submucosa through the defect, there was no true protrusion forming a sac as in Experiment 1.

*Microscopic Examination*—Section showed that the muscularis had been completely removed and that the mucosa bulged through to the level of the surrounding serosa.

*Experiment 3*—A young adult female mongrel terrier was operated on, March 20, 1922, under ether anesthesia, the appendix and cecum being mobilized and the appendiceal-cecal junction carefully freed, care being taken to injure as few as possible of the large vessels in the mesentery. After crushing with clamps, the base of the appendix was divided, phenol was applied to the stump, and it was inverted into the cecum and buried by suture. The distal divided end was first opened, so that a small piece of cork about 8 mm in diameter could be inserted into it, and then phenol was applied, and it was inverted and buried by suture. There was some soiling by appendiceal contents during this stage of the operation. A defect 5 mm square was made in the wall of the appendix over the cork, exposing the submucosa. At once, the appendix contracted, and the mucosa and submucosa protruded through the defect, forming a small dome shaped swelling about 2 mm high. This persisted. The wound was then closed. This operation produced a completely segregated appendix with a foreign body in it and a diverticulum.

The dog developed distemper, and died April 10, twenty-one days after operation.

*Necropsy* (April 11, 1922, twenty-seven hours after death)—There was a suppurative tracheitis, bronchitis and beginning bronchopneumonia. Considerable postmortem discoloration was noted in the peritoneal cavity. The region of the appendix was completely covered with firmly adherent omentum. When this was separated, the appendix was found lying just as at operation. The diverticulum was well defined and appeared as before. The cork was now in the lumen, but slightly nearer the tip. There was no distention of the segregated appendix. The intestines were empty except for a minimal amount of fecal material in the large intestine. The duodenum, with the pancreas in its mesentery, had become intimately adherent to the site of operation. Fluid could be passed only with difficulty through the cecum. After distention with liquor formaldehydi, the whole area was removed for study. When the specimens were opened, it was found that the appendix had perforated and there was a closed

abscess cavity outside the base, the walls of which were formed by the cecum, duodenum and pancreas. The cork lay just beyond the site of the diverticulum. The lumen of the appendix was not dilated, averaging 3 to 5 mm in diameter. It contained some cloudy fluid mixed with debris. The diverticulum measured 1 cm where it passed through the muscularis, and it projected for a distance of 3 mm above the surrounding serous surface. The cecum, where the wall had been inverted, was sharply angulated and its lumen reduced to a semilunar slit, 6 mm from horn to horn and 0.5 mm at its broadest point. There was fecal material, however, on both sides of this narrowed area.

*Microscopic Examination*—Sections of the diverticulum revealed a bulging of submucosa, muscularis, mucosae and mucosa through a defect in the muscularis. None of the muscularis remained over the denuded submucosal surface. Sections made through the point of perforation of the appendix and the abscess cavity revealed that the walls of the latter were made up of adherent duodenum and cecum, both of which were relatively normal except that the serosal surfaces were covered with a necrotic layer where they bordered the abscess cavity, and there was a portion of pancreas which presented extensive degenerative and fibrotic changes. The abscess cavity contained many mononuclear cells and a few leukocytes, together with much amorphous debris.

*Experiment 4*—A dog which was about to be killed was selected and anesthetized with ether. A defect 4 mm square was made in the appendix near its tip, down to the submucosa. The submucosa and mucosa at once protruded from 2 to 3 mm through the defect and at the same time the strong muscular contractions which involved the entire organ made it hard, shorter and of smaller diameter. It was observed for some minutes, during which time the muscular contractions were relaxed and then it contracted once more. During the period of relaxation, the diverticulum seemed to become somewhat flaccid, although its total projection was not less.

A metal syringe was now passed through a slit in the cecum up into the appendix and a silk ligature tied about the appendix base over the nozzle, in an attempt to make the appendix a closed cavity. Water was then injected. At first, the lumen of the appendix filled with water, which passed into the diverticulum, and it stood out as a firm, smooth hemisphere above the surrounding serosa. As more and more water was injected, the diameter of the appendix continued to grow greater, and as it did so, the projection of the diverticulum above the surrounding serosa grew steadily less, until there was no longer any projection at all, although the muscular defect had practically doubled in diameter. With all the force which could be exerted through the syringe, an attempt was made to burst the appendix, but this did not occur, as the increased tension caused the ligature tied about the base of the appendix to cut through so that it leaked at this point. The attempt was repeated several times, with the same result. The dog was then killed.

*Experiment 5*—A dog was killed with chloroform, and the peritoneal cavity was opened and left exposed to the air. From time to time, bits of serosa and muscularis were excised from the wall of both the large and the small intestine. Each time, there was the usual muscular contraction, resulting in the narrowing and shortening of the segment injured and a protusion of the submucosa and mucosa through the defect. As time passed, the force of the muscular contraction grew more feeble until, about four hours after the death of the animal, there was no longer any response to the injury. The extent of the protrusion through the gap was variable, and seemed to be influenced by the

# SUMMARY OF CASES OF DIVERTICULA OF APPENDIX

Case	Sex *	Age	Previous Attacks of Acute Appendicitis	Habitually Constipated	Removed During Acute Attack	Diverticulum Involved in Acute Inflammation	Duration of Acute Symptoms	Position of Appendix	Lumen of Appendix Obstructed Between Diverticulum and Cecum		Diameter of Diverticulum, Mm	Diverticulum				Vessels Alongside Neck of Diverticulum	Width of Broadest Vascular Defect in Mesenteric Border of Muscularis, Mm	Vascular Defects Seen in Antimesenteric Border	Greatest Thickness of Muscularis, Mm	Whole Lumen Diverted	Associated Condition		
1	♀	46	?	?	At necropsy	In one		Pelvic brim	By Angulation or Twisting	By Obstruction of Lumen and Mucosa	From 3 to 4	3	2	0	1	0	0	1	No	2	1		
2	♂	30	No	No	Yes	In one	3 days	Laterocolic	Probably	In one	From 3 to 5	2	1	0	1	0	0	12	Yes	15	1		
3	♀ (colored)	20	Probably not	Yes	No			Retrocecal and retroperitoneal	Possibly (aspirated feces in it)	Yes	5	1	1	0	0	0	0	0	No	1	1	Salpingitis cystic ovary, fibromyoma	
4	♂	54	No	?	Yes	Yes	1½ days	Behind ileocecal junction	No	No	5	1	1	0	0	0	0	15	Yes	?	1		
5	♂	21	6 in 1 year	Yes	Yes	In one	10 hours	Infracecal	No	Yes	From 4 to 10	3	3	0	0	0	0	0	5	Yes	22	No	
6	♀	28	1	?	No			Pelvic	No	No	From 3 to 5	7	3	3	1	0	0	10	Yes	27	No		
7	♂	20	4 or 5	Yes	Yes	No	2 days	Retrocecal	Yes	No	5	1	0	0	0	1	0	?	?	2	No		

\* In this column 0 indicates female.

\* In this column ♀ indicates female ♂ male

amount of the contents of the lumen. When a loop was emptied of its contents, however, and a defect then made with the contraction of the muscular tissue there was a protrusion.

When there was no longer any response of the muscular tissue to injury, a defect was made through the muscularis of the appendix, exposing the submucosa, but no protrusion occurred through it. It was possible, by manipulation to force some of the loose flaccid mucosa and submucosa through the gap, and when manipulation ceased a fold remained projecting very slightly through the gap. When this procedure was repeated in the intestine, the results varied, if the loop selected was not empty, a protrusion followed the defect, if it was empty no protrusion occurred.

A syringe was then inserted through the cecum into the appendix and tied into place. When it was distended through this as in Experiment 4, the first result was the protrusion of the flaccid mucosa and submucosa, forming a smoothly rounded hemisphere above the surrounding serosa. With the tension increased, the sequence of events was exactly the same as in Experiment 4. The diameter and length of the appendix slowly increased while the projection of the diverticulum grew steadily less, until it ceased entirely. Attempts to burst it succeeded only in causing leaks where the ligature was tied about the base of the appendix.

*Experiment 6*—C. D., aged 33, married, American, a housewife, during the previous four months had had three attacks of acute, cramplike pain, starting in the epigastrium, and radiating to the lower quadrant and around both sides to the back, with vomiting. A bowel movement gave relief. The attacks lasted about one day, and tenderness persisted in the right lateral quadrant after attacks. On examination, there was tenderness in the right lower quadrant and right fornix. The white blood cells numbered 10,600, polymorphonuclears 70 per cent. The temperature was 98.8 F. Aug. 25, 1922, three days after admission appendectomy was performed by Dr. Freeman, Jr. supervised by Dr. W. B. Parsons. The appendix was retrocecal and twisted on itself. The proximal two thirds was covered by a vascular veil.

This appendix was taken immediately after removal and laid on a cork mat beside a millimeter scale. A defect 6 by 6 mm. was made through the muscularis of the antimesenteric border near the tip. When first laid out, the length of the appendix was 72 cm. and the average diameter 6.5 mm. At the end of fifteen minutes, it measured in length 6 cm. and in diameter 7.5 mm. At the end of one hour, it measured in length 5.5 cm. and in diameter 7.5 mm. During the first few minutes, the submucosa and mucosa pouted through the muscular defect until they projected 1 mm. beyond the serosa. They remained in this position without change during the rest of the hour of observation.

The appendix was then distended with fluid through the cut end. It passed freely to the tip and, with the inflow of fluid, the appendix increased in length up to 7 cm., and the projection of submucosa and mucosa through the defect returned within the muscular wall, so that the diverticulum was ironed out and disappeared.

The appendix was then fixed in liquor formaldehydi. On longitudinal section, the muscularis was found to vary from 0.4 to 0.9 mm. in thickness. Microscopic sections revealed some scarring of the inner muscular coat and round cell infiltration of all the coats.

The patient made a good recovery, and the appendix was believed to have been the seat of the trouble.

# PRIMARY CARCINOMA OF THE MALE URETHRA \*

HERMAN L KRETSCHMER, M D

CHICAGO

Carcinoma of the male urethra is generally considered a rare disease. In 1907 Preiswerk<sup>1</sup> reported two cases and made a careful review of the literature, which at that time contained reports of forty cases, to which he added his two.

Since 1907 isolated case reports have been published, but, as far as I am aware, no extensive review of the literature has appeared. In a recent review, I have been able to find reports of thirty-seven cases, but some of these were published prior to 1907 and evidently were overlooked by Preiswerk. If this number is added to the forty-two cases previously reported, the total is seventy-nine. With the case recently under my observation, which I shall report herewith, the total number at present is eighty. J W Thompson Walker's<sup>2</sup> three cases, because of the lack of data, are not included in the foregoing calculation.

Aside from the interest in this disease, due to its rarity, the case herewith reported is interesting because of its pathology. The gross and microscopic pathology was that of a papillary carcinoma, a rare type of urethral carcinoma, since the largest number hitherto reported have been of the pavement or squamous-cell type. In addition to the papillary carcinoma, the entire urethra was studded with benign papillomas.

## REPORT OF CASE

*History*—Dr N, aged 53, referred by Dr Ralph Hissem, was admitted to the Presbyterian Hospital, Feb 16, 1921, complaining of swelling, induration and tenderness of the shaft of the penis with fistula formation, enlarged inguinal glands, frequency and burning on urination, and urgency and dribbling afterward. He had had the usual diseases of childhood. There was no history of venereal disease. Twenty-five years previously, a large mass of papilloma had been removed from the urethra with a curet.

In November, 1920, the patient had experienced some irritation about the glans. There was a discharge from the urethra, perhaps due to the presence of a very long prepuce. He had had similar trouble several times, because of a long prepuce, and he had consulted a physician who advised argyrol injections, but by mistake he had used Hartzell's solution (iodin crystals, 50 grains, zinc iodid, 15 grains, potassium iodid, 15 grains, water,  $\frac{1}{2}$  ounce, and glycerin,  $\frac{1}{2}$  ounce). In about an hour, the prepuce became enormously swollen, the next day blood exuded from the meatus, followed several days later by swelling of the penis. Difficulty of urination occurred, and his condition

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\* Read before the Chicago Pathological Society, Feb 12, 1923.

1 Preiswerk Ztschr f Urol 1 273, 1907

2 Walker, J W T Surgical Diseases and Injuries of the Genito Urinary Organs, New York, Funk and Wagnalls Company, 1914

became worse. An abscess formed on the inferior surface of the penis, which was lanced, December 15, resulting in the formation of a urinary fistula which had been present ever since, the opening having increased in size on account of an overgrowth of what was diagnosed at that time as granulation tissue. Numerous small abscesses had formed since, causing multiple fistulas. Acute retention occurred about the middle of December, at which time Dr. Hissem made a dorsal slit in order to expose the meatus. The penis was swollen to the size of the patient's forearm. He had fever, toxemia and extravasation of urine. Sounds up to a No. 31 were passed under ether and an indwelling catheter was inserted for four days. The bladder was irrigated because of pus, and sounds were passed every two or three days. The large sizes produced bleeding.

It was never noticed that the inguinal glands were enlarged until the last few days before admission. They were never tender. Frequency had been present until a month previously. Burning was present in the urethra during urination. Urgency was severe, the patient being unable to retain the urine at times. Dribbling occurred after urination. There was no hematuria, epididymitis nor backache.

*Physical Examination*—The patient presented the appearance of a fairly strong man. He was of slight build, and apparently was not acutely ill. Examination of the heart and lungs was negative. Neither tenderness nor masses were discovered in the abdomen.

*Genitalia*—Examination of the testicles was negative, the spermatic cords were tender but not enlarged. The inguinal glands on both sides were enlarged and slightly tender. The penis was greatly enlarged, being 7 cm. in diameter and about 20 cm. in length. On the lower surface, about the middle, was a mass of red granulation tissue, 3.5 cm. in diameter. Beside it was a fistula, 1 cm. in diameter. The urine flowed through this mass on urination. The shaft was very hard, not very tender and moderately reddened, and the induration extended down to the symphysis and then stopped. Posteriorly, it could be felt extending to the perineum. The prepuce was very thick. Pus was present at the meatus.

*Rectal Examination*—The prostate was small and soft, and the seminal vesicles were palpable.

*Blood Examination*—Leukocytes numbered 10,300; hemoglobin, 69 per cent. Blood pressure was systolic, 155, diastolic, 84. The Wassermann reaction was negative.

*Operation*—Feb. 26, 1921, under ether anesthesia, amputation of the penis, transplantation of the urethra into the perineum and removal of the inguinal glands en masse were carried out. The first step in the operation was the removal of the inguinal glands. The patient made an uneventful recovery.

*Histologic Examination*—The pieces removed from the large tumor showed papillary carcinoma.

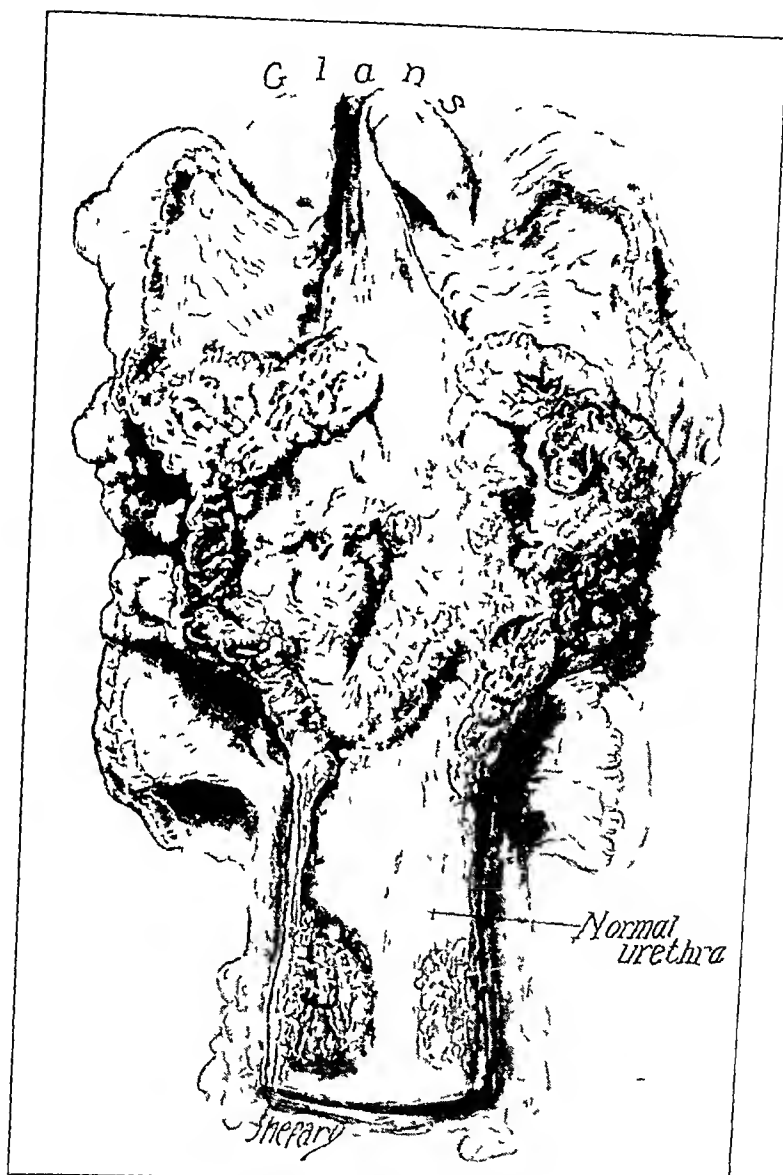
*Inguinal Glands*—Six different sections from six different glands revealed no evidence of carcinomatous infiltration. The glands were filled with large numbers of round cells. The diagnosis was chronic adenitis.

#### PATHOLOGY

Primary carcinoma of the male urethra may be classified as follows: (1) squamous-cell carcinoma, (2) columnar-cell carcinoma, (3) papillary carcinoma, and (4) adenocarcinoma.



The squamous-cell carcinoma is, by far, the most frequent type of carcinoma which occurs in the urethra. In Preiswerk's tabulation of thirty-nine cases, thirty-one belonged to this group. In the thirty-six cases collected in this review, twenty-four were of this type. Perhaps the total number of the squamous-cell type is even higher, since in some



Carcinoma of the urethra showing the presence of carcinoma just behind the glans. Two benign papillomas are seen just above the line of amputation.

of the case reports a diagnosis of carcinoma was made without stating the type of the cells. Normally, the prostatic urethra is lined with transitional epithelium and the penile urethra with columnar epithelium, only the fossa navicularis having squamous epithelium. The development of a squamous-cell carcinoma of the penile urethra can be

explained on the basis of metaplasia, as a result of which patches of leukoplakia form, which then undergo malignant degeneration. In the same manner, squamous-cell carcinomas occurring in other parts of the other urinary organs (in parts which do not normally contain squamous cells), such as the kidney pelvis and the urinary bladder, can be explained.

Columnar-cell carcinomas are quite rare. Only one of Preiswerk's collected cases belonged to this type, the one reported by Cabot. Of the cases in this series none was columnar-cell carcinoma.

The papillary carcinoma is as rare as the columnar-cell variety. Preiswerk included only one case of this type, the one reported by Buday. Subsequently, cases of this type were reported by English.<sup>3</sup>

The case reported in this paper showed, besides a large papillary carcinoma, many benign papillomas. It may be stated with reason that one of the previously benign tumors had undergone malignant change, a somewhat analogous condition occurring in certain bladder tumors.

When adenocarcinoma is found, the consensus of opinion is that its source is most frequently in Cowper's glands, hence this type has been considered as primary in Cowper's glands with secondary invasion of the urethra. In rare instances, it may happen that the tumor originates in some of the urethral glands, in which case it would be classified as a true adenocarcinoma.

The carcinoma may spread along the mucous membrane of the urethra. As the tumor enlarges, the lumen of the urethra is encroached upon, and the symptoms of stricture supervene. At times it extends into the spongy bodies, and not infrequently grows outward so that a palpable mass is present. Infection is a concomitant of the tumor, hence suppuration ensues, and the clinical picture is that of a peri-urethral abscess. Later fistulas may form with escape of urine through the fistulous opening. In the course of the disease, there is an early involvement of the inguinal glands, record of which involvement has been stated in fifteen cases. In one case, involvement of the lumbar glands was found at necropsy (Montgomery<sup>4</sup>).

#### ETIOLOGY

Nothing is known regarding the etiology, although several factors have been mentioned as playing a predisposing rôle.

**Age.** The one constant factor of importance, as in other forms of carcinoma, is age, the tumor being essentially one of advanced or late adult life. The youngest patient whose case is reported was 38 years

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<sup>3</sup> English. *Folia urolog* **1** 38-76, 1907-1908.

<sup>4</sup> Montgomery. *Med Chron* **1** 190-193, 1901.

old (Ropke<sup>5</sup>), and the oldest, 74 (Peacock<sup>6</sup>) Between the ages of 30 and 39, one case has been reported, between 40 and 49, seven cases, 50 and 59, eighteen cases, 60 and 69, seven cases, 70 and 79, two cases, and the age was not stated in two cases

**Stricture** Several authors have mentioned a history of long-standing stricture But, on the other hand, no history of stricture was found in a large number of cases, and many of the patients denied previous urethral infection, a matter reported by Barney,<sup>7</sup> Bierbaum,<sup>8</sup> Bonzani,<sup>9</sup> Hall,<sup>10</sup> Ropke, Montgomery, Platte,<sup>11</sup> Olivier and Clunet,<sup>12</sup> Romano,<sup>13</sup> Shattuck,<sup>14</sup> Scott<sup>15</sup> and Van Hook<sup>16</sup> Stricture should be regarded as a factor only so far as it might produce metaplasia or leukoplakia of the urethral mucosa An important point to remember, and one bearing on the subject of stricture, is that carcinoma may produce symptoms of stricture early in the course of the disease, and these symptoms may be wrongly interpreted

**Previous Venereal Disease** Since gonococcus infection of the male urethra is common, and carcinoma of this part of the body is rare, the assertion may be made that the gonococcus plays little, if any, etiologic rôle in the production of this disease A positive history of previous gonorrhea is mentioned by Barney, Braasch and Scholl,<sup>17</sup> Conforti,<sup>18</sup> Deveze,<sup>19</sup> English, Menard,<sup>20</sup> Michon,<sup>21</sup> Ottow,<sup>22</sup> O'Neil and Rizzì<sup>23</sup>

Regarding the part that preexisting local urethral conditions may play, it might be stated that in the case reported in this paper, the patient made the statement that twenty-five years previously many small papillary tumors were removed from the urethra by means of a curet, and many were found in the urethra after it was opened following the

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- 5 Ropke *Arch f klin Chir* **78** 233, 1905
  - 6 Peacock *Brit M J* **1** 138, 1910
  - 7 Barney, J D *Boston M & S J* **207** 790, 1907
  - 8 Bierbaum, K *Inaug Diss*, Leipzig, 1912
  - 9 Bonzani *Folia urolog* **3** 491, 1908-1909
  - 10 Hall, J B *Ann Surg* **39** 375, 384, 1904
  - 11 Platte *Med Chron* **44** 94-98, 1906
  - 12 Olivier and Clunet *Bull et mem Soc anat de Paris* **132** 735, 1907
  - 13 Romano *Riforma med* **28** 957, 1912
  - 14 Shattuck *Tr Path Soc Lond* **58** 199, 1906-1907
  - 15 Scott *Bull Cleveland General Hosp* **1** 30, 1899
  - 16 Van Hook *Chicago Med Rec* **12** 303, 1897
  - 17 Braasch, W F, and Scholl, A J, Jr *Ann Surg* **76** 246 (Aug) 1922
  - 18 Conforti *Clin chir* **16** 315 (Feb 28) 1908
  - 19 Deveze *Montpel med* **20** 193, 1905
  - 20 Menard *Bull et mem Soc anat de Paris* **135** 394, 1910
  - 21 Michon *Ass franç d'urol Proc-verb* **15** 342, 1911-1912
  - 22 Ottow *Ztschr f Urol* **7** 30, 1913
  - 23 Rizzì *Ztschr f Urol Chir* **7** 1 (July) 1921

amputation. Whether these papillomas are to be considered as predisposing factors may be questioned. However, since papillomas in the bladder often undergo malignant change, there is no reason why the same phenomenon cannot take place in urethral papillomas.

Of further interest in this connection is the patient's statement that he attributes his present condition to the use of an injection into the urethra of Hartzell's solution. Since his condition developed so rapidly after the use of this injection, it seems reasonable to assume that the injection fanned the carcinoma into activity. Prior to the injection, the tumor may not have been noticed by the patient.

#### SYMPTOMS

*First Stage*—Early in the course of the disease, the symptoms are practically nil. Often the first symptoms noted by the patient are those associated with stricture, which are caused by the obstruction produced within the lumen of the urethra by the tumor. Often the presence of a discharge first attracts the patient's attention to his local condition. Discharge was noted by Barney, Menard, Montgomery, Ottow, Peacock, Platte, Rizzi, O'Neil, Shattuck, Ropke, W. S. Scott, and in my patient. In O'Neil's case, there were gonococci in the discharge, and in Rizzi's case, the discharge was bloody. Definite obstruction to urination was noted by Bierbaum, English, Peacock, O'Neil, Rizzi and Tansini.<sup>24</sup>

Because of these symptoms in the early stage of the disease, the clinical picture is often confused with stricture, and the picture is still further complicated if the patient develops complete retention of urine after symptoms of urinary obstruction have been present for sometime. Retention of urine is not an uncommon symptom. Its presence was recorded by Barney, Bierbaum, Bonzani, Devezé, O'Neil, Olivier and Clunet and Ropke. A history of stricture was mentioned by Anzilotti,<sup>25</sup> Barney, Bierbaum, Bonzani, Braasch and Scholl, Devezé, Montgomery, Platte, Paul,<sup>26</sup> Ropke, O'Neil and Scott.

However, one should not forget that the carcinoma produces an obstruction which is a malignant stricture. This fact should be borne in mind in eliciting the history, particularly when trying to establish a history of previous stricture.

*Second Stage*—This stage of the disease may be characterized by the formation of a local tumor which may be the first symptom noted by the patient, hence this is the condition which causes him to consult a physician. Tumor is a common finding later in the course of the

<sup>24</sup> Tansini, quoted by Bonzani (Footnote 9)

<sup>25</sup> Anzilotti. Clin chir, Milan **12** 60, 105, 1904

<sup>26</sup> Paul. Lancet **1** 1127 (June 20) 1885

disease, as noted by Anzilotti, Barney, Bierbaum, Bonzani, Conforti, Deveze, English, Hall, Woods, Montgomery, Legueu,<sup>27</sup> Olivier and Clunet, Platte, Romano, O'Neil, Rizzi and Scott

*Third Stage*—As the disease progresses, infection supervenes, and there is superimposed the picture of a periurethral abscess, which has, indeed, nothing characteristic about it to distinguish it from any other type of periurethral abscess. If a patient with this type of abscess is brought into the hospital as an emergency case, the malignant nature of the condition is often not recognized, and this oversight can be readily understood. Periurethral abscess formation was present in cases reported by Barney, Hall, Lavenant,<sup>28</sup> O'Neil, Van Hook, Conforti, Deveze, English, Montgomery and Paul.

*Fourth Stage*—Still later, the clinical picture is further complicated by the presence of fistulas. Urinary fistulas occurred in the cases reported by Anzilotti, Barney, Bonzani, Conforti, English, Hall, Montgomery, Legueu, Lavenant, Menocal,<sup>29</sup> Platte, Van Hook, O'Neil, Paul and Ropke.

As a rule, the opening of the fistula, or fistulas, is on the under-surface of the penis, but it may be found on any surface. Thus, in Legueu's case it was found on the dorsum of the penis.

#### TREATMENT

Just as soon as the diagnosis has been made, nothing short of a radical operation should be employed, namely, amputation of the penis with transplantation of the urethra and complete extirpation of the inguinal glands. This type of operation was carried out in the case reported in this paper. When the patient was last heard from, two years after the operation, there were no signs of recurrence.

If the diagnosis is made early, that is, when the tumor is small and before there is involvement of the regional lymph glands, one might resort to the use of radium.

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27 Legueu *Med mod* **15** 313, 1904

28 Lavenant *Bull et mem Soc anat de Paris* **129** 666, 1904

29 Menocal *Rev de med y cirug de la Habana* **13** 133, 1908

# THE PATHOGENESIS OF PEPTIC ULCER †

J E SWEET, M D , L F BUCKMAN, M D , A THOMAS, M D ,

AND

E M BELL, M D

PHILADELPHIA

The etiology and pathology of gastric and duodenal ulcer have attracted the interest of investigators and clinical observers since the time of Cruveilhier, the more because of the fact that no satisfactory explanation has appeared. Many theories have been advanced, based on experimental investigation and clinical observation, and as many counter-theories and refutations, based on equally good material, have been called up in answer. The literature, therefore, abounds in probable theories of the causation, but everywhere one is impressed by the diversity of opinion and the variety of the avenues of approach employed by the investigators.

Our interest in the question was aroused by the observations reported from this laboratory by Ellis,<sup>1</sup> who found, in a few cases hemorrhagic erosions and even perforating ulcers in the stomach and duodenum of dogs after the intravenous injection of toxins isolated from animals with a high intestinal obstruction. Erosions and ulcers were also seen after the removal of the suprarenal bodies, an occurrence which has been reported by Finzi,<sup>2</sup> Mann,<sup>3</sup> Friedman,<sup>4</sup> Silvestri,<sup>5</sup> and others. The interesting observation was also reported by Ellis,<sup>1</sup> that the content of the intestine after double supraenalectomy, contains a poison identical with, or similar to, that found after high intestinal obstruction. The object of our experimentation was the attempt to produce ulcers by a functional high obstruction, by means of a blind duodenal pouch, and later by looping the upper intestine in various ways to produce chronic stasis.

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\* From the Department of Surgical Research, University of Pennsylvania School of Medicine.

1 Ellis, J W. The Cause of Death in High Intestinal Obstruction, *Ann Surg* **75** 429 (April) 1922.

2 Finzi, O. Ueber Veränderungen der Magenschleimhaut bei Tieren nach Nebennierenextirpation und über experimentell erzeugte Magengeschwüre, *Virchows Arch f path Anat* **214** 413, 1913.

3 Mann, Frank. Gastric Ulcer Following Removal of Adrenals, *J Exper Med* **23** 203 (Feb) 1916.

4 Friedman, G A. Probable Endocrine Origin of Peptic Ulcer, *J A M A* **71** 1543 (Nov 9) 1918.

5 Silvestri, T. Endocrine Origin of Gastric and Duodenal Ulcer, *Policlinico* **27**.673 (June 28) 1920.

It has been pointed out by many observers that the acute and chronic peptic ulcers are distinct from the superficial hemorrhagic erosions so often found in diseased and cachectic conditions. Our own observations were based on the assumption that a peptic ulcer is a circumscribed loss of tissue in the wall of the stomach or duodenum, surrounded by an area of reactive inflammation, and involving one or all of the coats of the intestine. Cruveilhier,<sup>6</sup> quoted by Bolton,<sup>7</sup> initiated the idea that chronic ulcer originated in acute lesions, and Rokitsky<sup>8</sup> subscribed to this view. Bolton believes that most acute ulcers heal rapidly, and that chronic ulcers result only from unhealed acute lesions. We accepted this view in our consideration of the problem, and advance the hypothesis that failure to heal, i.e., the chronicity of the ulcer, results from the continued pull of the muscle fibers about the margins of the ulcerated area. An ulcer which did not primarily extend into, or through, the muscularis would not become chronic, but would compare with the hemorrhagic erosion and readily heal.

In this connection, it is significant that Wilensky and Geist<sup>9</sup> reported that micro-organisms, isolated from human peptic ulcers and introduced into surgically produced ulcers in animals, have no influence in retarding healing or in the production of the chronic indurated ulcer. Ivy,<sup>10</sup> in describing the healing of the acute ulcer, points out the importance of the proliferation of connective tissue in the submucosa about the ulcer and the binding of the edge of the ulcer to the connective tissue base. Our conception of delay in healing is based on the assumption that the muscle fibers exert tension on the edges, preventing a reduction in size and the anchorage of the edge by connective tissue, and exerting the same influence on the healing process that constant movement exerts on a varicose ulcer of the leg.

Smithies<sup>11</sup> and Carlson<sup>12</sup> have produced evidence to show that high acidity of the gastric juice can have no influence in either the cause of ulcer or delay in healing. Bolton<sup>7</sup> and Friedman and Hamburger<sup>13</sup> secured delay in healing of acute ulcer by producing a partial

6 Cruveilhier. *Essai sur l'anatomie pathologique en general* 2 54, 30

7 Bolton, Charles. *Ulcer of the Stomach*, London, 1916

8 Rokitsky. *Lehrbuch der pathologischen Anatomie* (Sydenham Society) 2 31, 1849

9 Wilensky, A. O., and Geist, S. H. *Experimental Studies in Production of Chronic Gastric Ulcer*, J. A. M. A. 66 1382 (April 29) 1916

10 Ivy, A. C. *Studies on Gastric and Duodenal Ulcers*, J. A. M. A. 75 1540 (Dec. 4) 1920

11 Smithies, Frank. *Significance of Etiologic Factors in the Treatment of Peptic Ulcer*, J. A. M. A. 74 1555 (June 5) 1920

12 Carlson, A. J. *The Control of Hunger in Health and Disease*, Chicago, University of Chicago Press, 1916

13 Friedman, J. C., and Hamburger, W. W. *Experimental Chronic Gastric Ulcer*, J. A. M. A. 63 380 (Aug. 1) 1914

pyloric stenosis. The former says that the retention of bacteria and acidulated food causes continued infection and irritation of the ulcer, with the migration of leukocytes to the site and necrosis of the base, thus hindering the growth downward of regenerating glands. The process then results in the excessive formation of scar tissue, over which the mucous membrane fails to grow. It seems reasonable that the stenosis sets up hyperperistalsis, with resultant pull of the muscle fibers about the margins of the lesion.

On the basis, then, that all peptic ulcers start as an acute lesion, some perforating, the majority healing, the others progressing to a

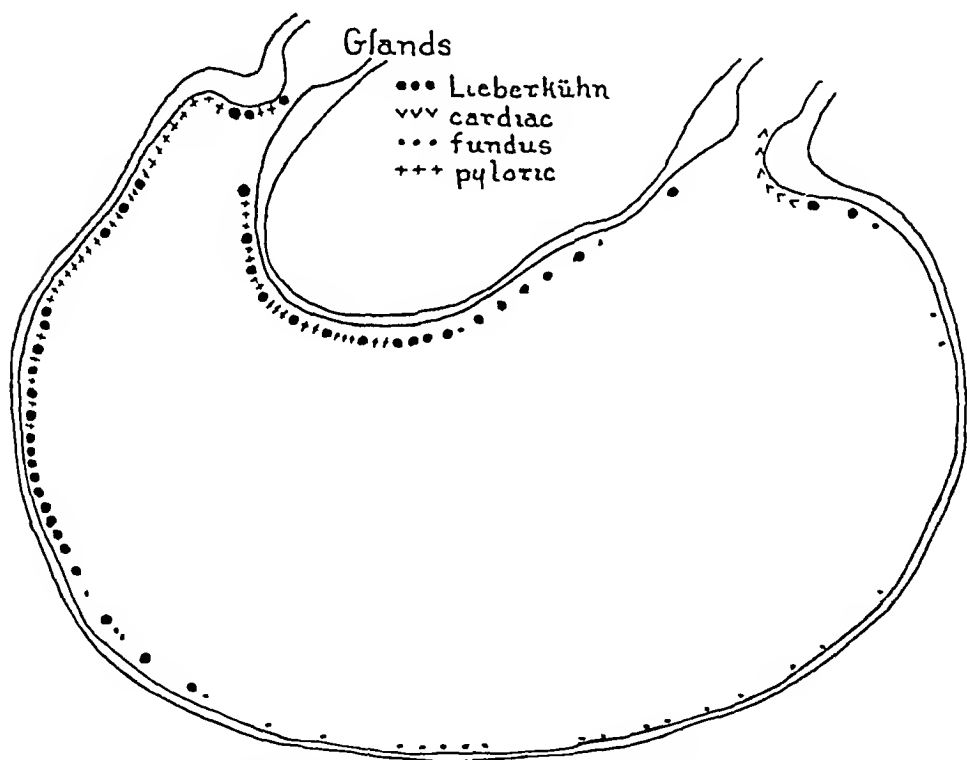


Fig 1—The arrangement of the glands along the two curvatures of the stomach (after Jovenel)

chronic stage, we endeavored to reproduce acute ulceration by functional obstruction of the duodenum. The animals used were dogs, under strict conditions of etherization and asepsis. The operation consisted of section of the duodenum at varying distances from the pylorus, ranging from 10 to 30 cm, closure of the cut ends, and anastomosis between the stomach and the distal segment of the small bowel. The dogs that survived showed the characteristic hypertrophy and distention of the blind duodenal tube, with erosions and hemorrhages. In no case could a distinct peptic ulcer be found.



The next supposition was that a chronic functional obstruction could be used as a condition favoring a low-grade, chronic toxemia, which might induce the formation of ulcers. Moynihan<sup>14</sup> points out the existence of a condition which might be the expression of a toxemia of intestinal origin, preceding the clinical signs of ulcer. "About one fifth of the patients who have gastric ulcers complain not only of pain, but of great prostration, feebleness, or lassitude coming on just at the time when pain is due. On close inquiry, this most distressing symptom may be found to have preceded the experience of pain by weeks and months. The periodicity of the two is identical."

Lane<sup>15</sup> attributes the formation of ulcer to stasis in the duodenum. Rénon and Blamautier<sup>16</sup> report perforations of the small bowel in the course of rectal carcinoma, and attribute the cause of ulcerations preceding perforation to the prolonged stagnation of intestinal chyme and marked pathogenic activity of the bacterial flora of the intestine. Finally, Wilkie<sup>17</sup> states that chronic duodenal ileus is sometimes found in association with duodenal and gastric ulcer, and says that in cases of rapid collapse and death after the perforation of a duodenal ulcer, the signs of chronic duodenal obstruction should be looked for.

Our first technic, designed to produce an artificial duodenal stasis, involved the section of the reflection of peritoneum attaching the duodenum to the posterior abdominal wall, the twisting of the duodenum on itself to make a partial volvulus of mild degree, and the anchoring of the loop by suturing it to the stump of the peritoneal reflection. All the animals that recovered from the operation continued to live an apparently normal existence and showed no signs of ulceration in the intestine.

Following this, we attempted a partial functional obstruction by surrounding the duodenum, at a level of about 14 cm. from the pylorus with bands of fascia dissected from the rectal sheath. The results in this series were as inconclusive as in the preceding cases. The walls of the duodenum proximal to the obstruction showed nothing more convincing than thickening and distention, with moderate infiltration of the mucosa by blood.

The next step was the production of a blind duodenal loop, with drainage through the distal segment, from a point above the loop or

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14 Moynihan, B. G. A. *Essays on Surgical Subjects*, Philadelphia, W. B. Saunders Company, 1921, p. 73.

15 Lane, W. A. *Operative Treatment of Chronic Intestinal Stasis*, New York, Oxford University Press, 1918, p. 44.

16 Renon, L., and Blamautier, P. *Ulcer and Perforation of Small Intestine in Case of Rectal Carcinoma*, *Bull. Acad. de med., Paris* **85**: 715 (June 21) 1921.

17 Wilkie, D. P. D. *Chronic Duodenal Ileus*, *Brit. M. J.* **2**: 793 (Nov. 12) 1921.

from the stomach. The duodenum was sectioned at a level about 25 cm from the pylorus and the proximal end carried back to be introduced into the duodenum above, by end-to-end anastomosis. The distal end was then introduced into the duodenum above the blind loop, in some cases, in other cases, into the stomach. The purpose of the operation was not to produce an absolute obstruction, but to establish a chronic functional obstruction, where stasis and a source of toxemia might be set up.

The results here were somewhat more encouraging. No dogs died of acute symptoms referable to gastro-intestinal disturbances. Dogs making complete and uneventful recovery were later killed and examined for evidences of ulceration. In only a few isolated cases were suggestions of an ulceration present. These were seen as localized hemorrhagic areas in the mucous membrane. In one case, this appeared in a suggestive location, i. e., on the lesser curvature in the pyloric antrum of the stomach. Our results must be acknowledged to be negative, so far as they concern the production of ulcer by a chronic functional obstruction with stasis.

The question now arises whether the development of ulcer depends on a mechanism which disturbs the physiology of the intestine, be it obstruction, chronic stasis, embolism, vessel spasm, disturbance of innervation, or any one of the numerous theoretical explanations presented in the literature, or does the genesis of the ulcer depend on some anomaly seated in the anatomic structure of the intestine?

The characteristic peptic ulcer is a punched-out lesion that "looks as if something had dropped out," and is not primarily spreading, while the edges of the punched-out hole show no signs of involvement whatever. The fact that this hole is round inclines us to believe that the vessels are not involved, for even the end arteries of the mucous membrane do not supply a perfectly circular area. Likewise areas of ischemia would not result in a perfectly round lesion, nor disturbances of innervation. An area of infection might be perfectly round, but the adjoining edges must show reactive infiltration. It suggests that something had been in that site which was wholly distinct in itself, different from the surrounding parts, and of itself only susceptible to the influences that produced the lesion. The thought would be that some element exists in the mucosa which lends itself to the disturbances which promote necrosis and ulceration.

Recently, Muller<sup>18</sup> pointed out that peptic ulcer occurs in those regions of the gastro-intestinal tract of embryologic importance in the stomach, at the region where there are islands of intestinal glands interspersed with gastric glands, in the esophagus where there are islands of gastric mucosa, in the duodenum and jejunum where there

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<sup>18</sup> Muller, P. Beitr. z. klin. Chir. **123** 1, 1921

are islands of pancreatic tissue, in Meckel's diverticulum where there are islands of gastric and pancreatic glands of incomplete anatomic structure, and, therefore, of abnormal function. Within such glands, he believes there can be an intracellular activation of digestive ferments, by virtue of which the glands themselves and their surroundings are digested.

Schafer<sup>19</sup> in Quain's "Anatomy" records that true crypts of Lieberkuhn occur in certain parts of the human stomach, similar in all respects to those of the small intestine. These are most numerous in a zone which lies between the area occupied by fundus glands and that occupied by pyloric glands, especially on the greater curvature.

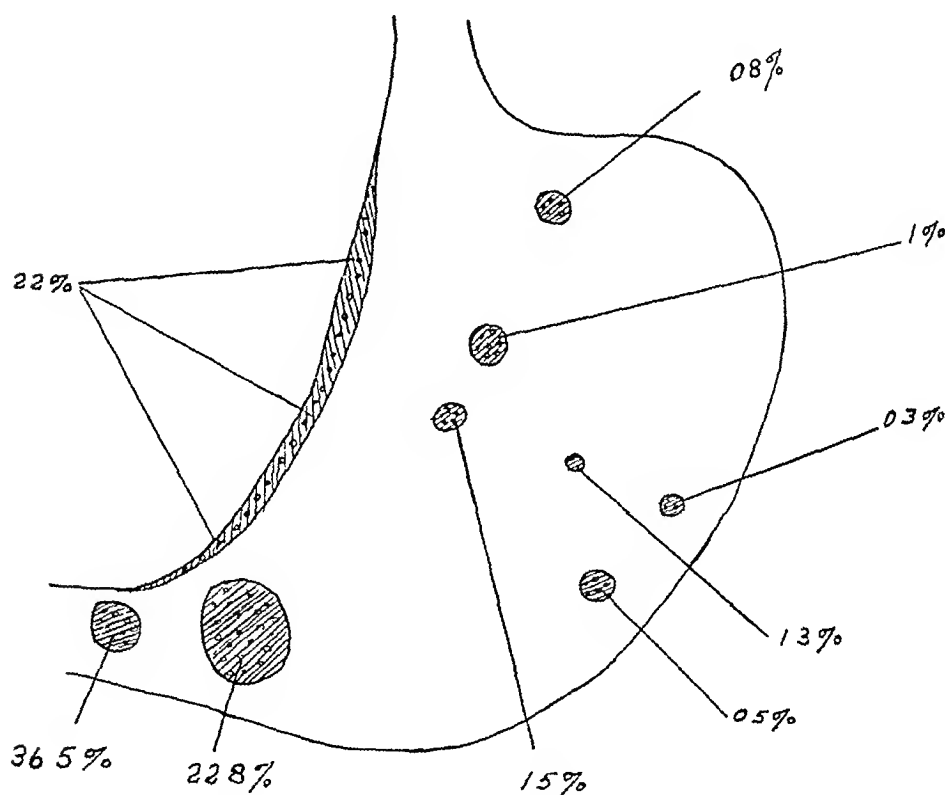


Fig 2—Areas of the stomach prone to ulcer, as determined by Krogius (from Dahl)

Attention was called to the presence of such crypts in the stomach mucosa by Schaffer<sup>20</sup>. Jouvenal<sup>21</sup> pointed out that the deepest cells of these crypts of Lieberkuhn also exhibit granules similar to those described by Paneth in the intestinal glands, and says that such intestinal glands, found in the gastric mucosa near the pylorus, consist of normal cells and do not represent a metaplastic process.

19 Schafer, E. A., in Quain "Elements of Anatomy," Ed 11 2 533, 1912

20 Schaffer, J. Sitzungsber. d. k. Akad. d. Wissensch., Wien 106 1897

21 Jouvenal, F. Répartition des Glandes de l'Estomac, J. de l'anat. et de la physiol 42 1, 1906

Muller<sup>18</sup> studied fresh ulcers from the operating room, and in a case of perforating ulcer of a Meckel's diverticulum, he found that the diverticulum contained gastric mucosa resembling that of the normal pylorus and fundus. Extending his study to ulcers of the stomach, he found intestinal glands in the immediate neighborhood of the gastric ulcer in two of three cases. Muller discusses the proposal of Hammschlag, that a transformation between gastric glands and intestinal glands occurs which accounts for the presence of aberrant intestinal glands in the gastric mucosa. Muller asserts that the histology and embryology oppose this transformation, pointing out that the intestinal glands occur in sharply separated island formations, not mixed with gastric cells, and showing no transitional forms. Furthermore, such intestinal glands have been shown to contain beaker cells and distinct Paneth cells, as seen in the glands in their normal location.

Dahl<sup>22</sup> discusses an earlier report of Muller,<sup>23</sup> and calls attention to the distribution of areas of intestinal mucosa in the stomach, which he believes become subjected to the action of gastric juice, with results disastrous to the abnormally situated tissue. On this basis, he would explain differences in the susceptibility of persons and sexes, and the inclination of ulcers to follow in families. Dahl includes in his paper the two schematic drawings which are reproduced herewith, since they afford a picture of the areas of the stomach in which these aberrant islands occur, and compares these areas with the areas prone to ulcer, as determined by Krogius from a study of 391 cases. It is significant that histologists<sup>24</sup> do not report the occurrence of gastric mucosa in parts of the intestine below the duodenum and upper jejunum, correspondingly, the pathologists do not commonly find peptic ulcers below these levels.

The thought occurs that these glands being located in a foreign field are more subject to adverse influences by reason of the unusual environment. Intestinal glands normally accustomed to the alkaline reaction of the small intestine must be exposed to acid secretion when transplanted to the stomach. Their existence might not be jeopardized despite the unusual atmosphere unless some disturbing influence makes its presence felt through an alteration in the supply of blood to the part. The formation of ulcer after suprarenalectomy is well proved, after

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22 Dahl, P. R. Sur la Pathologie de l'Ulcere, Arch. d. mal. de l'app. digestif **10** 483 (April) 1920.

23 Muller, P. Beitr. z. klin. Chr. **115** 560, 1919.

24 Broman, I. Verhandl. d. anat. Gesellsch. **27** 14, 1913. Also Kaufmann, E. Anat. Anz. **28** 465, 1906. Bensley, R. B. Am. J. Anat. **2**. Schaffer, J. Virchows Arch. f. path. Anat. **177** 181, 1904. Kull, H. Anat. Anz. **41** 609, 1912. Arch. f. mikr. Anat. **77** 541, 1911. Trallero, M. "Ueber das Verhalten der Muscularis Mucosae der Magenschleimhautinseln im Oesophagus," 1913, Dissert. med., Berlin.

suprarenalectomy, we also observe a steady fall in blood pressure. This is easily reflected in the stomach as an ischemia, which may lower the vitality and resistance of such intestinal gland cell rests to a degree which would not affect the normal mucosa, but would leave the aberrant tissue susceptible of destruction.

An ischemia or a stasis of blood to the part might well result in an asphyxiation, which in turn permits an autolysis, with the formation of an unknown substance, having the power of activating the proenzyme of the duodenojejunal glands intracellularly.<sup>25</sup> There would then follow an autodigestion, without any surrounding reactive inflammation. Thus, it is conceivable that the characteristic punched-out ulcer, looking "as if something had dropped out," would result, corresponding exactly to the isolated patch of aberrant intestinal glands, and no more, and "looking as if something had dropped out," because something had dropped out.

The question of the mode of formation in the duodenum now suggests itself. Deaver and Reimann,<sup>26</sup> in a study of recent ulcers, report two cases of duodenal ulcer removed at operation in which pancreatic tissue was found in the intestinal wall at the base of the ulcer, without any connection with the pancreas itself. Here the suggestion offers itself that a relic of embryologic defect is represented by the island of pancreatic tissue in that neighborhood of the intestine whence the pancreas developed, and that no disturbance arose from it until induced by such a disturbance as ischemia and asphyxiation which are supposed to occur in the case of gastric ulcer. Here there might be an activation of trypsin, with resultant autodigestion and a clean, punched-out ulcer corresponding only to the island of aberrant tissue.

Kaufmann<sup>27</sup> reports an accessory pancreas found at the tip of Meckel's diverticulum. Gegenbauer (1863), quoted by Broman,<sup>28</sup> called attention to an accessory pancreas in man, occurring usually in the jejunum and existing without any connection with the main pancreas. Broman saw a phylogenetic basis for an accessory pancreas in man, since in the lower forms the pancreas is represented by accessory glands distributed along the upper portion of the intestine.

The question in part becomes one of embryologic development and inherited tendency. Naturally the occurrence of peptic ulcers in the lower animals is rare. Turck<sup>28</sup> reported necropsies on 189 healthy and

25 Sweet, J. E. *The Surgery of the Pancreas*, Alvarenga Prize Essay, 1915, *Internat. Clinics* 4: 293, 1915.

26 Deaver, J. B., and Reimann, S. P. *Surgical Treatment and Pathology of Gastric and Duodenal Ulcer*, *Surg., Gynec. & Obst.* 32: 103 (Feb.) 1921.

27 Kaufmann, E. *Lehrbuch der speziellen pathologischen Anatomie*, Berlin, G. Reimer 1: 641, 1911.

28 Turck, F. B. *Intestinal Venous Stasis*, *J. A. M. A.* 67: 1784 (Dec. 9) 1916.

eighty-two diseased dogs, in which the findings of "peptic ulcer" were absolutely negative. Mann<sup>7</sup> listed a series of more than 200 normal dogs and cats in which "no lesion of the gastric mucosa was found at autopsy." Ivy,<sup>29</sup> in studying 900 dogs in his laboratory which had been subjected to two or three hours of ether for experimental purposes, found, in diseased and cachectic animals, only two marked ulcerations. On the other hand, Cohnheim<sup>30</sup> reported 1,086 cases of gastric or duodenal ulcer, being 7 per cent of 15,500 patients in the course of twenty years.

It is conceivable that by generations of natural selection in the lower animals strains showing a tendency to peptic ulcer have been bred out, as, indeed the commercial value of animal eugenics has led to the breeding out of all forms of inheritable defects, whereas in man, with no control of breeding and under medical and surgical care, "ulcer families" have been preserved to propagate their tendencies to abnormal cell-rests. Hence, we find the influence of age, sex and family exerting its impression in the etiology of the condition.

It is difficult to conceive that a bacterial embolism will affect only a small circumscribed round area and produce a characteristic ulcer in the face of the richly anastomosing gastric vessels. Mechanical abrasion and digestion by gastric juice are difficult of conception when we consider how neatly the injured mucosa recuperates following an operative procedure involving section of the entire gastric wall, even in the face of the high acidity which normally follows such trauma.<sup>11</sup> Section of the splanchnics, suprarenalectomy or the injection of highly toxic substances admittedly produce ulceration, but we would like to subscribe to the hypothesis of Muller, that these are contributing causes only, that the basic cause is the autolysis of islands of pancreatic and intestinal gland rests, attendant on the lowered vitality enhanced by the disturbance of the contributing causes.

This hypothesis would explain the findings reported by Ellis<sup>1</sup> of perforating ulcer in some instances following the intravenous injection of the toxin of high intestinal obstruction. Ellis concluded that the only explanation of the origin of the toxin consistent with his experimental results is that under the conditions of the high obstruction, of suprarenalectomy, etc., some factor activates the proteolytic proferment formed by the intestinal mucosa within the cells, instead of, as normally, outside the cell, in the lumen of the intestine. The necropsy on an animal dying from the effects of the intravenous injection of this toxin offers a very striking picture. The mucosa of the intestine, beginning sharply at the line where gastric mucosa and duodenal mucosa meet,

29 Ivy, A. C. Contributions to the Physiology of the Stomach. LII. Studies on Gastric Ulcer, Arch. Int. Med. 25:6 (Jan.) 1920.

30 Cohnheim, P. Arch. f. Verdauungskr. 27:241, 1921.

presents a condition of dark, velvet red, hemorrhagic infiltration. Islands of intestinal mucosa in the stomach would presumably show a similar effect, and, in addition, would be subjected to the digestive action of still another enzyme besides the one activated within the cells—the pepsin of the stomach.

In the consideration of human ulcer, it might not be amiss to point out, as regards due influence of age, sex, familial tendency and seasonal recurrence, the experimental fact that anaphylaxis in the dog presents an intestinal picture practically identical with that produced by the toxin of high obstruction.

The proof of this thesis might not lend itself to ready experimentation, but Muller's suggestion should be worth considering as an argument in favor of a more careful study, such as is seen in the report of Deaver and Reimann, of the bases and surrounding parts of ulcers, with an extension of the study to a careful microscopic examination of the nearby parts of the intestinal wall.

# CALCIFICATION AND OSSIFICATION OF THE MENINGES

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Calcification and ossification of the meninges have held the interest of pathologists and anatomists for many generations, and the numerous workers who have investigated the subject have brought to light so much information concerning them that our present knowledge of this subject seems almost complete. However, the importance of the roentgen ray in the diagnosis of cranial pathology and the fact that calcification and ossification of the meninges are to be considered in the interpretation of all roentgenograms of the head make a reconsideration of this subject appropriate. Bony new growths in the dura are found frequently in the animal kingdom. They are present in the falx of the dolphin, the seal, the platibus (*Omnithorhynchus paradoxus*) and in the tentorium of cats, bears, horses and pachyderms<sup>1</sup>.

The first reported instance of ossification of the meninges in man was probably that of Antonius Cattus<sup>2</sup> in 1557. In 1761 appeared Morgagni's "De Sedibus et Causis Morborum," in which were described two cases of ossification of the dura. Morgagni thought the symptoms were due to ossification. In one case, that of an apoplectic, between the leaves of the falx cerebri was a piece of bone of moderate thickness which was three finger-breadths long by one and one-half finger-breadths wide. The other case was that of a syphilitic patient who had had severe headaches and convulsions during the last months of his illness. In the falx cerebri were five pieces of bone attached to one another, so that scarcely one third of the falx was free from bone. In 1859, Molas<sup>3</sup> reported finding a piece of bone "of large dimensions" between the layers of the falx. In 1866, Jeannerat<sup>4</sup> found that in not

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1 Aschoff Pathologische Anatomie

2 Cattus, cited by Cruveilhier Traite d'anatomie pathologique generale, Paris, 1849

3 Molas Piece osseuse developpee entre les deux feuillets de la faux du cerveau, Compt rend Acad d sc 49 299, 1859

4 Jeannerat, Stanislas Des ossifications de la dure-mere, Strasbourg, 1866



less than sixty-four of 625 necropsies were the dura mater and falciiform process the seats of ossification

In these cases, eighty-eight pieces of bone were found in the falciiform process, and thirty-nine were found in the remaining parts of the dura. The bone formations were of three types: first, the plate forms which numbered sixty-five, of which fifty-one were in the falx (the largest, 8 by 18 by 0.7 cm) and fourteen in the remaining portions of the dura; second, the stalactite forms which numbered thirty-five; and third, the kernel or granular forms, which numbered twenty-seven.

The finding of many pieces of bone of considerable size has been reported. In Winkler's<sup>5</sup> case the bone measured 9.2 by 5.5 cm. In *Schmidt's Jahrbuch der in- und ausländischen gesammten Medizin*, 1858, the presence of a plaque, 7 by 7 by 1 cm, is reported. Burle and Morel<sup>6</sup> report a case with a plaque shaped like an oyster shell in the anterior part of the falx, measuring 6 by 3 cm. In Jackson's<sup>7</sup> case, the anterior two thirds of the falx was ossified. The plate of bone resembled a scythe blade, was about 4 inches (10.6 cm) in length, 1 inch (2.5 cm) wide and one-half inch (1.27 cm) thick at the anterior extremity, and one-half inch (1.27 cm) wide and one-fourth inch (6.3 mm) thick at the posterior extremity. The surfaces of the plate were rough. Cruveilhier has described complete calcareous metamorphosis of the posterior third of the falciiform process.

The ossifications are generally found in the falx, alongside the superior longitudinal sinus, especially where the falx is inserted into the crista galli, less frequently in other parts of the dura and most rarely in the tentorium cerebelli. They are never found in the dura which covers the base of the skull.

These ossifications are not to be confused with the calcareous deposits in the form of psammoma bodies or corpora amylacea which, in varying stages of development and of varying sizes, are of common occurrence in the arachnoidea of man and of the lower animals. Cushing and Weed<sup>8</sup> believe that, associated with this process of calcification, a hyperplasia of the arachnoidal mesothelium is liable to occur. The deposits of lime salt are apparently laid down in cell bodies, and, in this membrane, can bear no relation to the blood vessels. The occurrence of true bone formation in the arachnoid of man should be regarded as a similar phenomenon, except that one may consider the process of ossification to be proliferative rather than degenerative.

5 Winkler. *Inaug. Diss.*

6 Burle and Morel. *Osteome de la dure-mere*, *Lyon med.* **114** 1095, 1910.

7 Jackson, W. R. *Med. News* **54** 477, 1889.

8 Cushing, Harvey, and Weed, L. H. *Calcareous and Osseous Deposits in the Arachnoidea*, *Bull. Johns Hopkins Hosp.* **26** 367, 1915.

Zanda<sup>9</sup> reports sixty-three cases of osteoma of the arachnoid, and he believes that the ossification arises from the direct transformation of connective tissue into bone tissue by the deposition of calcium salts. If this is so, calcification and ossification may be considered to be closely allied processes.

Ewing<sup>10</sup> notes that multiple nodules of bone are found in the cerebral and spinal arachnoid in a considerable portion of cachetic subjects, and especially in the insane and epileptic. He says that Zanda has found that these nodules form about small vessels through degeneration, exfoliation and sclerosis of the endothelial cells and connective tissue, which form hyaline, then osteoid, and finally bone tissue. From these nodules, the bone plates develop.

Borst<sup>11</sup> speaks of leptomeningitis ossificans as a process in the pia mater, characterized by irregular plates of osteoid substance. The bone plates are partly the product of chronic inflammation with secondary calcification and, possibly, are formed in part from the osteogenic tissue of the skull by separation.

In embryonal life, the dura functions as the periosteum of the inner surface of the skull and is capable as such of osteogenesis. It is not to be wondered, as Ribbert<sup>12</sup> remarks, that we frequently find bony deposits which generally do not appear as tumors but as irregular plates. He believes that such plates as are found in the falx cerebri are probably formed from islands of bone forming tissue which are left behind in the differentiation of the dura. These bone formations are not strictly to be designated as tumors.

Although there is no age at which persons are exempt from calcification and ossification of the dura, those of advanced years show a certain predilection. Koester<sup>13</sup> quotes Netter as describing a case in a 12 year old girl.

The exostoses on the inner side of the skull resemble closely the ossifications which appear in the dura mater. The latter result from increased bone production of the outer layers of the dura mater and early are fused with the skull. The meningeal exostoses, according to Virchow, are always separated from the bone by a fibrous layer, thereby preserving their heteroplastic character.

Calcification, by which is meant the mere deposition of calcium salts in distinction to the more complex process of ossification or actual bone formation, occurs in the human body under varying conditions and in

9 Zanda Ziegler's Beitr. z. path. Anat. 5, 1889

10 Ewing, James Neoplastic Diseases, Ed. 2, Philadelphia, W. B. Saunders Company, 1922

11 Borst Die Lehre von den Geschwulsten, p. 166

12 Ribbert Geschwulste Lehre, p. 200

13 Koester Knochenbildungen in den meningen, Würzburg 1903

various places Nunokawa's<sup>14</sup> classification is a very serviceable one. He divides the calcifications as follows:

1 Calcification due to insufficient nutrition

- (a) of thrombi,
- (b) of hematomas,
- (c) of tumors of the skin,
- (d) of the insertion ring of the bicuspid valve in senility,
- (e) of the artery walls in arteriosclerosis,
- (f) of hyaline degeneration of blood vessels,
- (g) of unattached appendices epiploicae,
- (h) of the kidneys and the seminal vesicles in senility,
- (i) of placental villi,
- (j) of inflamed indurations of the pleura and peritoneum,
- (k) of chronically inflamed heart valves,
- (l) of different tumors

2 Calcification after sudden necrosis

- (a) muscle fibers near a wound,
- (b) muscle fibers made necrotic by ligature,
- (c) anemic heart infarcts,
- (d) ganglion cells of the brain and cord killed by trauma,
- (e) kidney, after certain poisons (mercuric chlorid),
- (f) lithopedion

3 Calcification metastases (Virchow)

In this class, local disturbances of bone cause the freeing of calcium salts which are deposited elsewhere, notably in (a) the endocardium, (b) the pachymeninx cerebri, (c) the stomach or intestine

4 Calcium deposits in thickened exudates, foreign bodies in the cavities lined by mucous membrane (as in the nose, tonsillar crypts, bronchi, intestine and the vagina)

5 Unexplained calcifications, such as those in the lung and muscle

Virchow classifies bone tumors into (a) the hyperplastic, which are entirely bone tumors arising from the osseous system and in which an abnormally increased production of bone is added to bone which is already present, and (b) the heteroplastic bone tumors which are entirely ossifications, arising in organs of the body not in conjunction with normal bone, and which in no way naturally tend to bone formation

Pathologic calcification is of two types chemically (1) that which appears in tissue poor in fats and which corresponds in its synthesis to that of "bone soil," that is, it contains tricalcium phosphates and calcium carbonates in a quantity relationship similar to that in the bone, and (2) calcification of fat tissues (as lipomas), which, on the other hand, can follow the deposition of calcium soaps

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<sup>14</sup> Nunokawa, K. Ueber Verkalkung der Pachymeninx bei Usura Cranii, Virchows Arch f path Anat 198 271, 1909

In order to ascertain how well the blood and lymph are able to function in the transportation of calcium phosphate, Hofmeister<sup>15</sup> added, to the blood serum, calcium salts and sodium phosphate in varying quantities and in varying alkalinities, and found that the blood serum was able to hold in solution much more of the resultant calcium phosphate than it was possible to dissolve in water. This power of holding in solution diminished with dilution. In albumin concentrations, such as are found in the tissue lymph, the power of holding this salt in solution is very much diminished.

The researches of Dr. Tanaka have demonstrated the solubility of ivory plates, bone plates and tooth fragments in fluids (water, salt solutions and blood serum) which have been saturated with carbonic acid. His work confirms the previous researches of Maly and Donat, Flesch and Tillmans that the solvent power is very considerable.

In water and salt solution, a square centimeter of bone surface at 37 C gave off about 0.15 gm of substance (mostly calcium phosphate).

For explanation of the resorption and erosion of adult bone, it is sufficient to say that the tissue lymph of the osteoclasts and other cells which bathe the bone tissue contains so much free carbonic acid that it exercises a dissolving action.

If tissue fluids which hold calcium phosphate dissolved by carbonic acid lose their content of free carbonic acid through giving off to the outside or through combination with an alkaline medium, it is possible that their active fluid movements or higher albumin content does not prevent the deposition of calcium phosphate.

If a slow stream of dilute soda solution is allowed to run through a tube with semipermeable walls, as, for example, a reed, and if this tube is submerged in a solution of calcium phosphate which has been dissolved by carbonic acid, the wall of the tube becomes encrusted, in a characteristic manner, partly with amorphous and partly with spherical, formed calcium phosphates. This may account for the repeatedly observed calcification of the interior of arteries and the walls of capillaries.

In the same way may be explained what otherwise would be very difficult to understand, namely, the appearance of metastatic calcification in lung alveoli and stomach mucosa from the giving off of acid (carbonic acid, hydrochloric acid), which occurs in these places. In this connection, it is noteworthy that the metastatic calcium deposits in the mucosa of the stomach closely correspond to the extent of the investing cells.

Experiments of Tanaka have shown that an oversaturation of the tissues with calcium salts, even in the absence of predisposing pathologic changes, tends to cause calcification.

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<sup>15</sup> Hofmeister. Experimentelles über Gewebes-Verkalkung, München med. Wchnschr. 1909, p. 1977.

Injection of chlorids, lactates, acetates, carbonates, or phosphates in the peritoneal cavity or in the tissues of rabbits, dogs, etc., have, as a result, more or less extended and occasionally widely dispersed the calcification of the neighboring tissues, even, now and then, into widely separated regions. Moreover, there appears directly in the peritoneal cavity or in calcium carbonate which has been brought through a reed, a gradual transformation into phosphates.

A simple explanation of the deposition of calcium soaps in necrotic or autolytically changed fat tissues is now available. This may also readily be imitated in experiments. If one takes fat tissue, and, at 37 C., treats it with a stream of calcium phosphate held in solution by carbonic acid, in a short time there will be macroscopic and chemical evidence of calcified fat tissue. This is due to a gradual fat splitting, whereby the liberated fatty acids act as calcium binders.

One cannot yet definitely explain the frequently observed calcification of dead or undernourished tissues.

Wells<sup>16</sup> divides pathologic calcification into two forms: one a precipitation of calcium in secretions and excretions of the body, the other, the deposition of calcium salts in the tissues themselves. He believes that normal ossification and pathologic calcification (except metastatic calcification and the calcification of fat necrosis and other areas of necrotic fat tissue) depend more on physicochemical factors and variations in the carbon dioxide concentration than on the presence of chemical precipitates in the tissues. An increase in the alkalinity of the fluids makes the calcium salts decidedly less soluble, and when there is excretion of acids, the fluids in the substance of the organs are correspondingly alkaline.

The following considerations are concerned with the appearance of calcification in degenerating tissues: (1) the increased alkalinity or decreased carbon dioxide in the degenerating tissues, causing precipitation of the inorganic salts in the fluids seeping slowly through them, (2) utilization of the protein of the fluids by the starved tissues so completely, because of its flow through them, that the calcium cannot be held longer in solution, (3) the formation within the degenerating area of a substance or substances having a special affinity for calcium, (4) production of a physical condition favoring the local absorption of salts, the least soluble salts accumulating in excess.

Thiroloux and DuPasquier<sup>17</sup> report the case of a patient dying from a cerebral hemorrhage in whom there was an ossified plaque, 8 by 6

16 Wells, H. G. *Chemical Pathology*, Ed 3, Philadelphia, W. B. Saunders Company, 1918, p. 435.

17 Thiroloux and DuPasquier. *Ossification de la dura-mère morte par hémorrhagie cérébrale*, Bull. Soc. anat. de Paris 68 38, 1893.

inches, in the dura mater. They believed that the dura took on an osteogenetic function because of the congestion.

Microbic agents are thought by some to play a part in the causation of certain varieties of calcification of the meninges. Lutembacher<sup>18</sup> reports a case of a woman dying of typhoid fever, in whom the tiny fibrous plaques adherent to the visceral surface of the spinal arachnoid contained typhoid bacilli. In another instance,<sup>19</sup> fibrous plaques were found which enclosed the meningococcus.

While authors agree that the bone is in relation to the dura, there is a difference of opinion as to whether or not it is primary in the dura, as Virchow, Borst and Kaufman contend, or whether it develops first in the arachnoid, and then as fully developed bone is attached to the dura (Cruveilhier, Otto).

The causes have been given as (1) inflammation caused by trauma (Elsner), (2) disturbance of nutrition (Virchow), (3) displacement of osteogenetic tissue (Ribbert and Borst), (4) irritation of the dura caused by displaced particles of the skull, or, more often by hyperemia, both of which result in ossification, and the etiology was reported as unknown by Forster, Schmaus and Borst.

Weber<sup>20</sup> summarizes his study of the subject in part as follows:

1 Ossifications of the dura belong not to the class of genuine tumors but to inflammations.

2 Such ossification, especially when it occurs in the sinus wall, as a rule, probably on account of disturbances of nutrition, appears first in the outer parts of the dura and then gradually spreads out centrally.

3 It may further thrombose of the superior longitudinal sinus.

The significance of ossification and calcification of the meninges has aroused the speculative interest of observers for a long time. The earlier men, quite naturally, on finding an ossified falx at necropsy, sought symptoms, generally mental, to attribute to it. But before long, it became apparent that the calcification occurred in mentally sound persons, and, moreover, were not even common in the insane.

In Wood's<sup>21</sup> case, there were four pieces of bone in the falx, the largest three-fourths by one-fourth inch (19 by 6.3 mm), and this author thought that the paralysis of the patient's left arm and leg was of interest in connection with the ossification of the falx. In a case in

18 Lutembacher, M. R. *Ann. de med.* 5: 148, 1918.

19 Lutembacher, M. R. *Plaques fibreuses de l'arachnoïde en clavant des meningocoques*, *Ann. de med.* 8: 51, 1920.

20 Weber, Richard. *Ueber das "Osteoma duræ Matris" und seine Beziehungen zum Sinus longitudinalis superior*, Zurich, Gebr. Leemann & Co., 1912.

21 Wood, H. C. *Bony Deposit in the Falx, Softening in the Pons Varolii*, *Philad. M. Times* 12: 350, 1881-1882.

which there was "irritation of the nerve centers," Morgan<sup>22</sup> thought such symptoms were accounted for by a small plate of bone in the right side of the falx cerebri. In a case of mania, Sneve<sup>23</sup> found a piece of bone, 4 by 1 cm by 6.25 mm, between the layers of the falx cerebri.

More lately, the conception of calcium metastases, to which Virchow's name is attached, has attracted study and interest. Wells calls attention to the fact that in conditions with much destruction of bone, as osteomalacia, caries and osteosarcoma, deposits of lime salts have been found distributed diffusely in various organs, particularly in the lungs and stomach. As much as 13.38 per cent of the dry weight of the lung and 12.15 per cent of the kidney have been found as calcium monoxide in such a case.<sup>24</sup>

In *usura cranii*, the condition of circumscribed osteoporosis of the skull, deposits of calcium have been found in the dura. Chiari<sup>25</sup> and Orth<sup>26</sup> called attention to this in 1909, and the latter reported the case of a child, aged 11½ years, who had a round-cell sarcoma of the pedunculus cerebri, in whom the dura, posteriorly in the midline, contained hard white plaques. Nunokawa,<sup>14</sup> a pupil of Chiari's, made further investigation along this line. In another communication, Orth<sup>27</sup> mentions the frequency with which the calcium deposits of the dura are found in cases of bone resorption of the skull.

Allenbach<sup>28</sup> further elaborates the theory that the calcium salts set free by the osteoporosis are deposited metastatically elsewhere. He reports two cases in which at operation white calcium deposits in the pachymeninx were noticed by the operators, who, accordingly, felt justified in making a diagnosis of *usura cranii*. Allenbach maintains that calcification of the pachymeninx is always a sign that the brain pressure must have acted long enough and strongly enough to call forth a *usura* of the skull, thereby making possible a calcium metastasis to the dura. Schmidt<sup>29</sup> noted that there were macroscopic calcium deposits on the outer surface of the dura, and that, in the corresponding places, the skull was atrophied and rough, a condition which occurs where most pressure is exerted. This writer studied the normal dura

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22 Morgan, C. W. Case of Osseous Formation of the Dura Mater, *Australasian M. Gaz.* **4** 35, 1884.

23 Sneve, H. An Unusual Osseous Growth in the Falx Cerebri, *Med. News* **54** 320, 1889.

24 Virchow's *Arch. f. path. Anat.* **197** 172, 1909.

25 Chiari. Zur Kenntnis der path. Verkalkung, *München med. Wchnschr.* 1909, p. 481.

26 Orth. *Charité-Ann.* **33** 376, 1909.

27 Orth. Bemerkung zu Allenbach's Arbeit, *Virchow's Arch. f. path. Anat.* **205** 274, 1911.

28 Allenbach. *Virchow's Arch. f. path. Anat.* **205** 474, 1911.

29 Schmidt, H. *Virchow's Arch. f. path. Anat.* **115** 142, 1914.

by a special microscopic technic and found that, after the age of 17 years, it contained calcium, and, after 40 years, there was as much calcium in some duras as there was in brain tumors

Another writer<sup>30</sup> notes that calcification of the pachymeninx not only is found in usua crani but also is sometimes quite widespread in inflammatory growths

There has been to date no roentgenographic study of calcifications of the meninges. By means of stereoscopic roentgenograms of the skull it is possible to demonstrate calcified plaques in the falx and perhaps even in the parietal dura. A roentgenogram of the head of the cat reveals very plainly diffuse calcification of the falx with the sharp curving inferior border. In the case reported herewith, in which operation was performed by one of us (A E H) for tumor of the brain, the roentgen ray revealed shadows which doubtless were due to calcification in the falx.

#### REPORT OF CASE

*History*—M B, a colored woman, aged 38, was admitted to the medical service of Dr Robert B Preble at St Luke's Hospital, Chicago, Oct, 1, 1921. The complaints on admission were (1) frontal and occipital headaches which had been very severe, having lasted from five to ten minutes at a time and having occurred frequently every day for the previous three weeks, (2) vomiting, which began two days after the headaches started and which was not projectile in character, (3) dizziness, (4) double vision, and (5) numbness, weakness and muscular twitchings of the right arm and leg. The patient had had three miscarriages. The left breast had been amputated two years previously for "cancer." Otherwise, the history was negative.

*Examination*—This revealed (1) slight rigidity of the neck, (2) double neuroretinitis, with hemorrhages from the retinal vessels (Dr Frank Brawley), (3) marked choked disk, slight paresis of the right side of the face, right hemiparesis, inclination to fall toward the right, a right palpebral fissure narrower than the left (Dr George W Hall). The blood Wassermann reaction was negative. The spinal fluid examination showed (a) negative Wassermann reaction, (b) positive Pandy test, (c) faintly positive Ross-Jones test. Examination of the urine was negative except for a trace of albumin. The roentgen-ray examination of the skull by Dr E L Jenkinson was reported thus:

"Extending downward from the frontal bone are many irregular areas of increased density which may be due either to new bone involving the internal table of the frontal or to ossification in the falx [as in the accompanying illustration]. There are areas of ossification which have no connection with the frontal bone. I believe the areas of ossification are located in the median line, as there is no difference in the size of the areas taken in the right and left lateral positions. If the deposits were in the frontal bone there should be definite changes in their sizes when the right and left sides are exposed. In other words, if the deposits were located in the right frontal they would be smaller when the right side was near the film and vice versa. The plaques

30 Saltykow, S. Zur Kenntnis der Duraverkalkung bei Schadelusur. Verhandl d deutsch path Gesellsch 17 521, 1914.



ranged in size from 0.5 to 1 cm in diameter. The total area involved measured about 6 by 3 cm. The ossification seemed confined to what we believe is the anterior third of the falx. The tentorium cerebelli shows no areas of ossification.

*"Summary Ossification of the falx cerebri"*

*Operation*—The patient's condition became worse, and Dr. Hall advised a left subtemporal decompression. Oct. 13, 1921, the patient was transferred to the surgical service of Dr. Albert E. Halstead, and a left subtemporal decom-



Lateral view of skull, showing the irregular, curved shadows just posterior to, and above, the frontal sinus, which were interpreted as being caused by calcified plaques in the falx cerebri.

pression, accomplished by elevating a bone flap, was performed by Dr. Halstead. The dura was opened, and no hemorrhage was found. Following this operation the patient improved steadily, was up and about, Oct. 16, 1921, and was discharged, Oct. 24, 1921.

*Readmission*—She was readmitted to St. Luke's Hospital Jan. 21, 1922. Her complaint at this time was inability to talk properly and paralysis of the right arm and leg. Examination disclosed a pulsating cerebral hernia in the left temporal region. There was complete right hemiplegia, including the facial

nerve She was also suffering from aphasia The left palpebral fissure was wide, and the eyeball seemed to protrude There was a neuroretinitis, with papillitis of 2 diopters An attempt to inject the lateral ventricles with air through a trephin opening was made, but the patient's condition became so serious that the operation was discontinued The patient was unimproved and was discharged, March 11, 1922

*Subsequent Note*—The social service department found that the patient died at home, July 11, 1922 Necropsy was not performed

#### CONCLUSIONS

From the foregoing considerations the following conclusions may be deduced

- 1 Ossification and calcification of the meninges are not rare
- 2 Areas of ossification may arise from (a) the retention of the osteogenetic function by islands of dura, (b) an inflammatory process
- 3 Areas of calcification may arise as (a) the result of a not far distant absorption of calcium of the skull and its subsequent deposition in the meninges, (b) the result of an inflammatory process
- 4 In cases of suspected brain tumor, the demonstration by means of the roentgenogram of calcification of the meninges is an additional evidence of the existence of a brain tumor exerting a circumscribed pressure on the skull
- 5 The chance finding of ossification or calcification in roentgenograms of the head affords the occasion for an intensive neurologic study of the case in question

# TWENTIETH REPORT OF PROGRESS IN ORTHOPEDIC SURGERY †

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## CONGENITAL CONDITIONS

*Congenital Dislocation of the Shoulder*—Todd,<sup>1</sup> in examining the shoulder joint of 730 subjects in the dissecting room of Western Reserve Medical School, found three cases of what he terms posterior congenital dislocation of the shoulder of the subacromial type. The chief deformity is in the scapula, the glenoid being rotated backward on the blade. There is a drooping of the acromion, and while the humeral head remains in articulation with the glenoid, its configuration may be changed. In this series, there were no congenital dislocations of the radius or of the femur.

*Congenital Defects of the Spine and Ribs*—Sever,<sup>2</sup> in a study of more than 2,000 roentgenograms of the spine, taken at the Boston Children's Hospital for various reasons, found twenty-two cases of cervical ribs, in nine of which there were other deformities of the vertebrae or ribs. In twenty-six cases, there were defects of the vertebrae in the dorsal region, with rib defects and scoliotic deformities. Lack of fusion of the spinous processes and laminae cannot be regarded as abnormal until after the seventh year, when they normally fuse. Eighteen true defects of the lumbar spine and sixteen of the sacrum were discovered. These two latter defects were often combined.

*Reduction of Congenital Dislocation of the Hip*—Goyder<sup>3</sup> has employed with satisfaction a push rather than a pull method of reduction of congenital dislocation of the hip. He believes less trauma and more perfect control are possible by this procedure. In the manipulation of a left hip, the sacrum is placed on a sand bag, and the pelvis

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\* This Report of Progress is based on a review of 516 articles selected from 610 titles dealing with orthopedic surgery, appearing in medical literature between May 21, 1922, and October 20, 1922. Only those papers which seem to represent progress have been selected for note and comment.

1 Todd. *Ann of Surg*, July, 1922.

2 Sever. *Boston M & S J*, June 15, 1922, p 799.

3 Goyder. *Brit M J*, Sept 16, 1922, p 497.

is steadied by an assistant. The left knee and hip are flexed, the hip as fully as possible, until the knee lies as nearly as possible by the side of the trunk. The right hand of the operator is placed on the patient's left knee, and the operator strives (1) by downward pressure, to push the head toward the acetabulum, and (2) by rotation of the knee, to direct the movements of the head. The palm of the operator's left hand is placed against the great trochanter, with the thumb in front and the fingers on the neck of the femur behind. While the downward pressure on the knee is maintained with the right hand, an attempt is made, by lifting with the fingers of the left hand and depressing the right hand, with or without rotation, as is demanded, to place the head definitely below the acetabulum. It may require a little time to stretch the tissues below the acetabulum, but no great force is necessary. The last procedure is to relax the pressure on the knee while the forward position of the head is maintained, and the head will be found to sink gently into the acetabulum. Often, it will be found at this stage that reduction has become possible by the more usual method of lifting the head of the femur over the posterior lip of the acetabulum.

**Davis method.** Merrill,<sup>4</sup> having worked for many years with the late Dr. G. G. Davis of Philadelphia, feels that his method of reduction of congenital dislocation of the hip has the great merit of gentleness and perfect control, and that familiarity with the method should be more general. The essentials and order of the procedure are: direct pressure, flexion, internal rotation, abduction, external rotation. The patient is placed prone on a flat, firm table, evenly padded, and the leg is allowed to hang downward close to the side of the table. There are two phases of the procedure. 1. The pelvis is fixed by one assistant, while another grasps the foot and knee, flexing the thigh toward the axilla, internally rotating the thigh and making pressure toward the head of the femur in line of its axis, keeping the thigh close to the trunk. The operator directs these movements and makes pressure downward on the trochanter toward the tuberosity of the ischium. 2. When the head has been pushed to the posterior brim of the acetabulum, the operator grasps the knee and trochanter, extending and abducting the thigh toward the transverse plane of the pelvis, and, within the bounds of safety, making pressure on the trochanter toward the acetabulum, at the same time gently rotating the thigh inward and outward. If these procedures are not successful, the first phase is repeated until the head is pushed downward to the obturator groove. It is then carried upward through the cotyloid notch by means of external rotation and extension. The plaster cast is applied in what seems to be the most stable position for the individual case.

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<sup>4</sup> Merrill. *J. Bone & Joint Surg.* Oct., 1922, p. 789.

Denucé's Method Adams,<sup>5</sup> after a personal observation of Denucé's methods and results at Bordeaux, has been greatly impressed by both. The procedure closely resembles the manipulation of Ridlon, except that tight adductors, which have been powdered with talcum, are gradually stretched by gentle stroking by the operator's palm and thenar eminence downward in the longitudinal axis of the thigh. No violence or great force is used in any stage of the manipulation. The patient lies on his back. As the adductors become relaxed, the thigh is brought up to right angle flexion and full abduction. No attempt is made to reduce the hip until the thigh will lie on the table at right angles to the trunk. The operator stands beside the affected hip and flexes the thigh, the knee being carried across the trunk in the direction of the opposite axilla, and the thigh being firmly pressed down upon the anterior body wall. The knee is held high in this position, a slight push being exerted in line with the axis of the femur. The fingers of the operator's other hand are placed under and around the head, neck and trochanter, lifting upward and pressing the muscles in between the head and the side of the pelvis.

In the next step, circumduction, the knee is carried across the trunk toward the affected side and then slowly downward to the surface of the table, and gradually abducted. During this procedure, the fingers behind the head are held firmly in place and exert a lifting force. Circumduction is slowly continued until the thigh is brought to a right angle with the trunk and lies flat on the table, the assistant meantime holding the pelvis firmly by pressure on the opposite iliac crest and anterior superior spine. The head is now felt to come gradually forward and lodge in the acetabulum. The term "oozes in" has been applied. The limb is ordinarily put in 90 degrees of flexion and abduction, the plaster extending from the nipple line to the ankle. The child is sent home and kept recumbent for three months, when, frequently, the cast below the knee is removed. After six months, the cast is cut into a lower and an upper half, and daily applications of hot sand bags are made to the anterior surface, while the child lies in the posterior shell. Heliotherapy is instituted. The child is encouraged to lift and straighten the leg voluntarily. At the end of the ninth month, the whole cast is removed to allow active motion and exercises of the glutei. As an aid in these exercises the parents construct a water tight box and fill it with a brine solution so buoyant that the child bobs up and down in it. Weight bearing is allowed one year from the time of reduction.

*Results of Reduction of Congenital Dislocation of the Hip*—Fairbank<sup>6</sup> estimates that an anatomic cure ought to be obtained by manipu-

5 Adams, Z. B. *J. Bone & Joint Surg.* July 1922, p. 523.

6 Fairbank. *Brit. J. Surg.* July 1922.

lative reduction in about 75 per cent of the unilateral and 50 per cent of the bilateral cases in the early years (before the age of 6). In the vast majority, function, for many years at least, should be excellent. Some successes may be obtained by a second manipulation if the first fails, but he recommends an open operation within two or three weeks of the second attempt. The operation which he advocates is not an open reduction, but an attempt to make an upper lip for the shallow acetabulum without opening the joint. Open reduction should be reserved for those cases in the middle age group in which manipulative procedures have failed. In only carefully selected cases should open operation be performed after the age of 6 years.

Evans<sup>7</sup> has been impressed with the bad results which follow attempts by untrained surgeons to reduce congenital dislocations of the hip.

*Report of Commission to Investigate the Best Methods of Treatment of Congenital Dislocation of the Hip*—The commission appointed by the American Orthopaedic Association, consisting of Goldthwait, Adams and Willard<sup>8</sup> emphasizes the importance of careful study of the individual case before and after operation. The depth and conformation of the acetabulum, the shape of the femoral head and the angulation of the neck, as well as the axis of the epiphyseal cartilage, are of great importance in prognosis. The commission is convinced that the violence used in reduction bears a direct relation to the large number of abnormally shaped heads which must make good permanent function less likely. They believe that the methods of Ridlon and Denuce are the best thus far devised. They consider that, of the machine methods, Hibb's is the least objectionable. It resembles the procedures of Ridlon and Denuce except that the forward movement of the head, once it has been drawn down sufficiently, is accomplished mechanically instead of manually.

Bernstein<sup>9</sup> reports the successful open reduction of a congenitally dislocated hip in a woman of 21, with 4 inches (10 cm.) of shortening. He removed a portion of the outer lip of the iliac crest and fastened it by bone screws over the upper lip of the acetabulum, in order to deepen the cavity. The gluteal muscles and the capsule were freely stripped down and out, and great force was necessary in traction to accomplish the reduction. The after pain was so severe that Bernstein recommends preliminary injection of the sacral canal to overcome the distressing symptoms of nerve stretching.

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<sup>7</sup> Evans. Brit J Surg, July, 1922.

<sup>8</sup> Goldthwait, J. E., Adams, Z. B., and Willard, DeF. P. J. Bone & Joint Surg., Oct., 1922, p. 821.

<sup>9</sup> Bernstein. I. Bone & Joint Surg., July, 1922, p. 481.

[ED NOTE —It seems to us interesting that strong advocates of the push rather than the pull method of reduction of congenital dislocation of the hip are coming forward. The procedures of Groyda, Schanz, Davis, Ridlon and Denuce have many points of similarity. The most striking common point is their gentleness and avoidance of trauma, not only to the femoral head, but also to the soft parts. The advantage of great gentleness is also strongly brought out by the report of the Commission of the American Orthopedic Association. Nothing can be more impressive than a series of roentgenograms of the femoral heads and acetabula taken years after successful manipulative reductions. A large proportion show changes in shape which must at least threaten permanent perfect function. Trauma at the time of reduction seems the most likely cause for these changes.]

*The Production of Temporary Paralysis in Difficult Cases of Congenital Dislocation of the Hip*—Robertson<sup>10</sup> advocates a method of producing temporary relaxation of the adductor muscles, the contraction of which he considers as much more important than the hour glass contraction of the capsule or the tension of the psoas muscle as an obstacle to reduction. Two weeks before the attempted reduction, he exposes the obturator nerve and ligates it with silk suture tied in a bow knot, the ends of which protrude through the wound. Beneath the first tie of the bow, another strand of silk is placed, the ends of which also protrude through the wound. The ligature may thus be untied and removed after the wound is closed. Constriction of the nerve maintained in this way for from one and one-half to two hours may be expected to produce a paralysis lasting for six months. The tendon of the adductor magnus is also divided at the adductor tubercle, since it has a separate nerve supply. He has employed the method also in securing alignment in certain difficult fractures of the long bones.

[ED NOTE —The Editors have had no experience with this method, but do not recommend it *a priori*. They are not convinced that the contraction of the adductors is the greatest obstacle to reduction, nor are they sure that a two weeks' paralysis of these muscles would sufficiently relax a long existing shortening. Moreover, it is rarely difficult to stretch the adductors, manually or mechanically, sufficiently to overcome the obstacle which they present to reduction, and after the head has been replaced, their tightness is rather to be desired as a retentive force. The most serious danger of Robertson's procedure would seem to be the lack of certainty as to return of power in the ligated nerve. In our experience, permanent damage to nerve supply has occasionally

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10 Robertson Surg Gynec & Obst, Aug, 1922 p 230

been suffered by accidental constrictions, which have been seemingly less complete and severe than that which the author deliberately produces ]

*Patella Bipartita*—Blencke<sup>11</sup> reports two cases of supernumerary patellae or double sesamoids. This condition is congenital, but in both his cases a trauma had been sustained, and the findings were supposed to be the result of the accidents. Blencke calls attention to the importance of making roentgenograms of both knees in industrial cases, and to the ruling out of a calcareous deposit in the prepatellar bursa, spontaneous fractures in tabes, etc. Patella bipartita may have its sesamoid at either the upper or the lower end, and there may be two or more fragments, looking at first sight like fractured pieces, but on close inspection found to have smooth, sharp, noncorrugated edges.

*Absence of Both Tibiae, Bone Transplants*—Congdon,<sup>12</sup> encountering a case of congenital absence of both tibiae in a 3 year old child who was much improved and made able to walk by bone transplanting operations, has made an interesting observation. In both legs, he discovered a piece of cartilage occupying the space of a portion of the proximal extremity of the tibia. In one leg, he preserved this, and brought it in contact with his grafts. Subsequent roentgenograms showed that ossification was taking place within the cartilage, and a more stable leg was gained on this side than on the other, from which some of this cartilage had been removed.

*Os Tibiale*—In eight cases of painful feet, Peltsohn<sup>13</sup> has found an os tibiale over the scaphoid. He was satisfied that this was the cause of the symptoms in pronated feet resulting from irritation of the syndesmosis, from strain of the tibialis posticus tendon. Plaster strapping and foot supports relieved the symptoms. Peltsohn calls attention to the relative frequency of supernumerary bones in cases of painful feet.

*Varus Deformity of the Humerus in Microcephalics and Cretins*—Merlini<sup>14</sup> has made a careful study of the humeri in cases of microcephalics and cretins. The normal angle of the humeral head with the shaft is from 140 to 150 degrees. The angle in microcephalics and cretins is from 104 to 126 degrees. He concludes that (1) varus deformity of the humerus occurs in 33 per cent of cretins and microcephalics, (2) the deformity never reaches an extreme degree, the angle never being more acute than 100 degrees, (3) this diminution in the angle is constant, the other deformities are variable, (4) a frequent if not constant peculiarity of the humeral head lies in the fact that the

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11 Blencke Ztschr f orthop Chir 42 291, 1922

12 Congdon Northwest Med, July, 1922

13 Peltsohn Klin Wchnschr, April 15, 1922 p 783

14 Merlini Chir de Org di Mov, July, 1922



articular cartilage, instead of ending at the margins of the head, is continued over the upper part of the anatomic neck and may cover even the greater tuberosity

#### RICKETS

Kjerrulf<sup>15</sup> calls attention to the fact that evidence of rickets is common in skeletons of children of the stone age found in Scandinavian countries. The first full description of the disease was given in 1554.

About 1600, it became very common in England, and spread over Europe almost in epidemic form. The literature on rachitis shows that the necessity for sunlight and fresh air has always been emphasized by physicians in the treatment, but it has taken nearly three hundred years to supply the scientific proof of the reasons why sunlight and fresh air are so indispensable.

Marfan<sup>16</sup> states that when rachitis develops before the child is 4 months old, the first evidences are noted in the skull. It next attacks the ribs, and last the bones of the limbs. In older children, the ribs exhibit the first changes, and the bones of the upper extremity are affected before the bones of the lower extremity. Roentgenography of the wrist is usually very instructive, the bones here being nearly always involved.

*Rickets in India*—Hess,<sup>17</sup> in the Cutter lecture at the Harvard Medical School, spoke of the occurrence of rickets in India. In the Nasik district of the Bombay Presidency, where the population is made up of an upper class of well-to-do Hindus, and a lower group of laborers, who are uneducated and poor, the incidence of the disease is most interesting. It occurs almost exclusively among the prosperous class. The dietary of this upper class is far superior to that of the lower class, among whom the disease is almost absent. The mode of life, however, of the first group, enforced by social and religious custom, particularly among the women and children, is largely an indoor existence. Screened from public view, they lack fresh air, sunlight and exercise. We must abandon the idea that rickets is necessarily a disease of poverty. It is to be found in the breast-fed infants of the well-to-do. It attacks chiefly those who lead an indoor existence.

*Vitamins and Rickets*—In an editorial in *The Journal of the American Medical Association*,<sup>18</sup> attention is called to the opinion of the Baltimore group of investigators that the power of certain fats to initiate the healing of rickets depends on the presence in them of a substance which is distinct from fat-soluble vitamin A. The facts seem to demonstrate

15 Kjerrulf *Hygiea*, July 16, 1922

16 Marfan *Nourrison*, May, 1922, p. 145

17 Hess, cited in *Rickets in India*, editorial, *J. A. M. A.* 78:1966 (June 24), 1922

18 A Specific Antirachitic Vitamin, editorial, *J. A. M. A.* 79:1050 (Sept. 23), 1922

the presence of a fourth vitamin in addition to the already known A, B and C factors. The specific property of this fourth vitamin, as far as it can be conjectured, would seem to be to regulate the metabolism of bone. Important as is cod liver oil in the treatment of rickets, it is evidently not the exclusive source of antirachitic potency.

*Experimental Rickets*—Shipley<sup>19</sup> well sums up the results of experimental studies in rickets. 1 Rickets is a disease of metabolism, usually due to faulty food. 2 It may be produced in rats by certain diets containing an improper balance between calcium and phosphorus, when an uncharacterized substance associated with certain fats is absent or deficiently supplied. 3 There are two kinds of rickets in rats: one, a low calcium type produced by diets relatively low in calcium but containing an approximately normal amount of phosphorus, other things being equal; the other, a low phosphorus type, produced by diets deficient in phosphorus, with a normal or high calcium content. 4 Some uncharacterized organic substance which is present in abundance in cod liver oil enables the organism to compensate for a defective calcium phosphate ratio in food. 5 Exposure to sunlight or to the rays of the quartz lamp (mercury vapor) will give the same result. 6 Either of these factors will induce healing in the bones of rachitic animals. 7 Starvation will also induce healing. These investigations leave a great many questions still unsettled. Some of them we are in a position to answer, others await further study.

*Ultraviolet Radiation*—Kramer, Casparis and Howland<sup>20</sup> report five cases in which children showing clinical evidences of rickets, confirmed by roentgen-ray examination, were treated by systematic exposure to the rays of a mercury vapor quartz lamp. Treatment was followed in every instance by healing of the rachitic process in the bones. The inorganic phosphorus concentration of the serum of these children was low (from 2.7 to 3.2 mg) before the treatment was initiated, but gradually increased to a maximum of 6 mg with the appearance of calcium deposition in bones. So far as could be judged, healing of the bones occurred at about the same rate after irradiation as after the administration of cod liver oil. The changes in the phosphorus concentration of the serum were identical with those found after treatment with cod liver oil. The pigmentation of the negro child's skin did not seem to interfere with the action of the light rays, colored children requiring no more intensive treatment to bring about healing than did white children.

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<sup>19</sup> Shipley, J. Bone & Joint Surg., Oct., 1922, p. 672.

<sup>20</sup> Kramer, B., Casparis, H., and Howland, J. Ultraviolet Radiation in Rickets, Am. J. Dis. Child. **24**: 20 (July) 1922.

*Carbon Light Treatment*—Hess and Unger<sup>21</sup> have employed in the treatment of rickets a carbon arc lamp similar to, but smaller than, that employed in the taking of motion pictures. The infants were exposed nude, except for eye coverings or spectacles, at a distance of from 3 to 9 feet, the exposure varying from fifteen minutes at 3 feet, to two hours at 9 feet. There was no tendency to superficial burn and no tanning of the skin (compare Rollier's theory of pigmentation). Eleven cases were so studied by clinical, chemical and roentgenologic examination repeated at least every month. In every instance, there was a rapid subsidence of the signs of rickets, as was evidenced by roentgen-ray examination, frequently after daily exposures for only two weeks. Improvement consisted of calcification of the lower epiphysis of the radius and ulna, which increased progressively as the treatment continued. Accompanying these changes was the constant increase in the inorganic phosphate of the blood, which in some cases had a tendency to fall after roentgenotherapy was discontinued. Animal experiments showed that carbon lamp exposures of three minutes daily at 3 feet were sufficient to bring about this protective effect.

*Adolescent Rickets*—Lewin<sup>22</sup> reports five cases of adolescent rickets. It seemed well established from the statements of the patients' families and earlier photographic records that the marked deformities which were exhibited, chiefly genu varum or genu valgum, had developed during the adolescent period, from 14 to 18 years. Some of these patients had had infantile rickets, but no cause was found for the adolescent condition other than a softened condition of the bones, resulting in a gradual and painless development of the gross deformity during the adolescent period. The disease apparently became quiescent, and operative correction of the deformity was successfully accomplished. Four of the five cases occurred in girls.

*Corrective Operations on Severe Rachitic Deformities*—Rhode<sup>23</sup> has employed the following technic in operating in cases of extreme rachitic bowing of the legs. His purpose is to obtain as complete correction as possible and insure regeneration. An Esmarch bandage is applied, and the periosteum is carefully dissected back at the seat of operation, being left in close contact with surrounding tissues. A piece of bone sufficiently large to enable a thorough correction of the deformity is subperiosteally resected, and the cavity temporarily packed with gauze soaked in warm saline solution. The resected piece is split by a saw, and the marrow is removed without being destroyed. The

21 Hess, A. F., and Unger, L. J. Use of Carbon Arc Light in Prevention and Cure of Rickets, *J. A. M. A.* 78 1596 (May 27) 1922

22 Lewin. *Surg., Gynec. & Obst.*, July, 1922

23 Rhode. *Arch. f. Orth.-u. Unfall-Chir.* 20 281, 1922

cortex is then cut into small pieces with a rongeur. The removed marrow surrounded by these cortical chips is placed in the wound cavity, and the periosteal tube and soft tissues and skin are tightly sutured about it. The Esmarch bandage is removed after the wound is closed, and blood fills the empty spaces inside the periosteal tube. The correction is now made, and plaster is applied, and is left on for three weeks, following which a second plaster is employed for four or five weeks. Some weight bearing is allowed with the second cast. The author reports firm union in eight or nine weeks after operation. In one of his cases, a wedge-shaped osteotomy, four months previously, had resulted in a pseudarthrosis. Union in this case, after Rhode's operation, was as prompt as in his other cases.

[ED NOTE—This procedure seems to the Editors to be unnecessarily complicated. An attempt is made to overcome difficulties (nonunion and incomplete correction) which, in their experience at least, occur only in exceptional cases, in which the simpler methods of osteoclasis and wedge-shaped osteotomy have been employed.]

#### SCOLIOSIS

*Treatment by Hinged Plasters*—Hanausek<sup>24</sup> has employed a plaster, cut horizontally and firmly united at the back by a hinge, with a horizontal axis placed at the junction of the two curves. The jacket is put on while the patient is in a standing position. The pressure is applied to the deformity of rotation, but no attempt is made to correct the lateral curve. Wooden levers are used daily on each half to rotate the spine. Sometimes the joint is fitted with cogs. Excellent results are shown in photographs taken eight months after the treatment was begun, and the improvement in the lateral curve is said to be as striking as the improvement in rotation. The article needs to be read to be appreciated.

*Fencing Position for the Application of Scoliosis Jackets*—Roederer's<sup>25</sup> illustrations also show good results in grave right dorsal, left lumbar curves from the application of jackets in the so-called fencing position. In a right dorsal, left lumbar curve, the subject is seated on the left buttock, the left knee is flexed, the right leg is extended backward, and the left arm forward, so that the right leg, the trunk and the left arm are in a straight line, forming an angle of 45 degrees with the floor. Fenestrae in the cast allow traction from both sides by means of broad bands. This form of application has been employed in thirty-two cases, and in one month the improvement is said to have been infinitely greater than by the Abbott method.

<sup>24</sup> Hanausek. Rev d'orthop, March, 1922, p 130

<sup>25</sup> Roederer. Paris med, July 15, 1922 p 1003

*Scoliosis Accompanying Chronic Open Pneumothorax*—Gurd,<sup>26</sup> after a long experience with chronic empyema, states that as a rule chronic infected open pneumothorax, if long continued, is followed by scoliosis. Curvature of the spine is toward the healthy side of the chest, and is consequent on pressure exerted on the spine by the contracting ribs of the diseased side. He has obtained correction of the deformity by means of extensive thoracotomy with removal and division of several ribs.

#### TUBERCULOSIS

*Primary Synovial Foci*—Rogers,<sup>27</sup> arguing from clinical observation, takes exception to the evidence presented by those who maintain that tuberculosis of the joints always arises from a focus in the bone, and that the joint structures are involved as a secondary infection. He feels that clinical evidence obtained from early operation on knee joints in which the articular surfaces are found macroscopically undiseased, while tubercle bacilli are found in excised synovial tissue, argues for at least occasional primary synovial membrane infection in tuberculosis, as in other infections. The progress of the disease as studied by the roentgen rays, he believes, suggests this also.

[ED. NOTE—While Rogers' clinical evidence is important and his views are shared by many surgeons, he must accept the burden of proof. In substance, Nichols and Allison and other laboratory investigators of tuberculosis of the joints say, "Give us a specimen of tuberculosis of the joints in any stage and we will find a bone focus which we believe to be primary to the synovial infection." It is difficult to obtain these specimens, if they exist, for such joints are not excised. Until it is done, however, and capable pathologists find in such joint material only synovial membrane and capsule tuberculosis, and are unable to find any focus in the bone, the discussion must needs go on, and the opinion of Rogers and many other able clinicians lacks positive proof.]

*Tuberculosis in Children as a State Problem*—Brown,<sup>28</sup> writing on the care of surgical tuberculosis in children in the commonwealth of Massachusetts, reaches the following conclusions:

1 At present, we have no accurate statistics in this state as to the number of nonpulmonary cases of tuberculosis. This lack is due to the physicians and hospitals of the state failing to report their cases. This can and should be corrected.

2 Surgery in tuberculosis of children is and always should be the exception, and it should always be made only an incident in the general and necessarily prolonged treatment.

<sup>26</sup> Gurd, F. B. *Scoliosis Accompanying Chronic Infected Open Pneumothorax*, Arch. Surg. 5:366 (Sept.) 1922.

<sup>27</sup> Rogers. I. *Bone & Joint Surg.*, Oct., 1922, p. 679.

<sup>28</sup> Brown. *Boston M. & S. J.*, Sept. 28, 1922, p. 470.

3 In children, operations for spinal immobilization are not advisable, and in adults without the proper postoperative care, do not give the results claimed

4 In tuberculosis of the spine in both children and adults, the ambulatory and supportive treatment has not given satisfactory results

5 In children, the ideal treatment is recumbency for at least from two to three years, followed by carefully observed and protected weight-bearing for two years more

6 In adults, in selected cases, the operation for spinal immobilization may be advisable, if it can be followed by at least six months' recumbency and a year or more of supportive treatment

7 There are no state or municipal hospitals with an adequate equipment or a personnel which can adequately carry out the proper prolonged treatment of recumbency and heliotherapy

8 It is the duty of the medical profession of the state to urge the legislature to provide adequate opportunity for the treatment of non-pulmonary as it is provided for pulmonary cases

*Tuberculosis of the Os Calcis*—Frisch,<sup>29</sup> before the Vienna Society of Physicians, presented a patient operated on by Gersuny eighteen years previously for tuberculosis of the os calcis, which had been excised, and the astragalus mobilized, so that its head occupied the place of the heel process of the os calcis. The patient had a normal gait and no subjective symptoms other than the slight discomfort of a flat foot

*Tuberculous Epiphysitis of the Great Trochanter*—Keith<sup>30</sup> reports a case of tuberculosis of the epiphysis of the great trochanter in a boy of 12. The physical and roentgenologic examination suggested a neoplasm. There were enlarged superficial veins, bone destruction, and the shadow of an outlined tumor, at operation shown to be an abscess. There was a history of injury. Keith thinks tuberculosis of the great trochanter more frequent than the literature would suggest

*Tuberculin Treatment of Bone and Joint Tuberculosis*—Graf<sup>31</sup> has administered tuberculin systematically in 100 cases of surgical tuberculosis in the course of heliotherapeutic treatment. His experience would seem to indicate that tuberculin is contraindicated in all such cases unless the process is sharply localized, torpid and obstinately refractory to other methods of treatment. Heliotherapy seems to reduce the tolerance for tuberculin

*A New Plaster Shell for the Treatment of Pott's Disease in Children*—Schwartz<sup>32</sup> emphasizes the importance of inducing the forma-

29 Frisch Munchen med Wchnschr, 1922, No 14, p 531

30 Keith Am J Roentgenol, Sept, 1922

31 Graf Deutsch Ztschr f Chir 171 57 (June) 1922

32 Schwartz J Bone & Joint Surg, Oct, 1922 p 789

tion of compensatory curves and modifying the shape of the spinous processes without separating the surfaces of the tuberculous vertebrae. The ordinary shell, hinged at the apex of the kyphos, was found by roentgenologic studies to be often applying the fulcrum unmechanically and incorrectly at different levels of the spine. In the frame or shell which he has devised, the head and thighs are supported, as well as the spine. An adjustable fulcrum is arranged as broad as the diseased area. At the level of the seventh dorsal vertebra, the fulcrum is placed opposite the apex of the kyphos. In lesions above the seventh dorsal vertebra, the fulcrum should be placed slightly below the apex of the kyphos. Approximately one quarter inch should be subtracted for each vertebra above this level. In lesions below the eighth dorsal vertebra, the fulcrum should be placed slightly above the apex of the kyphos, adding approximately one quarter inch for each vertebra below this level. Employment of the shell, mounted on uprights, permits the taking of lateral roentgenograms as controls of mechanical efficiency, while the patient is resting in it.

#### POLIOMYELITIS AND SPASTIC PARALYSIS

*Communicability and Serum Treatment of Poliomyelitis*—Amoss<sup>33</sup> summarizes the work from the Rockefeller Laboratory thus:

**Distribution of the virus in the host.** The virus has not been found in either the cerebrospinal fluid nor the blood of human subjects, but has been found in both in monkeys. The virus has been found in the nasal washings of both human and monkey cases. The definite time of disappearance has not been determined. There is doubt concerning the virus in the stools.

**Route of Infection.** It appears that the virus is transferred by chance either directly or indirectly from the nasal mucous membrane of the host to the nasal mucosa of the susceptible new host. It is propagated in the central nervous tissues of the host, but does not survive external conditions of mediation.

**Defense Mechanism.** The nasal washings of healthy adults, but not of children, neutralize the virus. In monkeys large doses intravenously rarely cause infection. It has been observed that a positive Schick test in poliomyelitic children is present twice as often as the expected occurrence in children of the same age in the general population.

**Carriers.** The virus seems to have a greater chance of surviving in the nasal secretions of a carrier than in the recovered case. Healthy carriers have been demonstrated.

**Communicability.** The stage of communicability is from one week before to two weeks after the onset.

**Prevention.** In Vermont the patient and the intimate contacts are quarantined for three weeks.

**Treatment.** Since the lesion is tucked away in the most remote and inaccessible parts of the body, treatment is a difficult art. Serum from recently recovered cases is recommended, as it is believed to have a greater antibody content. The serum for intraspinal injection must be free from particles and

33 Amoss. New York State J. Med., June, 1922, p. 256.

hemoglobin The results from serum treatment seem to show definitely when analyzed that the disease is arrested in cases treated within forty-eight hours after the onset with more than 50 c c of the serum

*Poliomyelitis During Influenza Epidemics*—Hiller<sup>34</sup> reports ten cases of affections of the spinal cord during a recent influenza epidemic in Dresden In six of the cases, the clinical picture was that of an acute anterior poliomyelitis In three, it resembled an acute diffuse myelitis, and in one there was a sudden paralysis of the bladder The latter patient recovered completely The paralysis in the others slowly retrogressed, but traces of it remained Hiller's study of the records shows an epidemic appearance of disease of the central nervous system in the great influenza epidemics of 1712 and 1889-1890

*Diagnosis, Prognosis, and Early Treatment of Poliomyelitis*—Lovett's<sup>35</sup> long experience makes the article of great value, especially in a disease in which every case is an individual anatomic study The special points he makes are 1 Diagnosis should be made on a basis of physical examination rather than on the history 2 Tenderness is a guide of great importance in diagnosis, prognosis, and treatment 3 Early treatment consists of rest 4 In the convalescent stage, muscle fatigue is our chief danger, and muscle reeducation our chief reliance 5 Deformities prevent proper function and favor muscular deterioration

*Treatment of Poliomyelitis in Children*—Girdlestone<sup>36</sup> describes the principles of treatment laid down by Sir Robert Jones At the onset, the child is wrapped in cotton wool and kept absolutely at rest for six weeks or more, plaster or retentive splints being applied over the wool Next comes the stage of gentle massage In the second stage, the principles carried out are (1) posturization of the trunk and limbs, (2) correction of deformities, (3) resumption of function of the ganglion cell and the affected part by slow stimulation of light massage, reeducation, guarded active movements and locomotion without overstrain Electricity is considered of doubtful value

*Acute Poliomyelitis in an Adult*—Winther<sup>37</sup> reports a carefully studied case of poliomyelitis of the Landry type, a sporadic one, running a very acute course, and fatal in eighteen hours Paralysis occurred as a result of the involvement of the anterior horn motor cells of the respiratory muscles first, the diaphragm (phrenic nerve), then the intercostal muscles, and finally the auxiliary respiratory muscles A detailed account is given of the histologic examination of the cord in the region involved

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34 Hiller Deutsch Arch f klin Med, May 5, 1922, p 143

35 Lovett, R W Diagnosis, Prognosis and Early Treatment of Poliomyelitis, J A M A 78 607 (May 27) 1922

36 Girdlestone Brit M J, Sept 20, 1922, p 596

37 Winther Hospitalstidende, July 5, 1922



*Accessory Muscle Movements in Deltoid Paralysis*—Pollock<sup>38</sup> discusses, on the basis of four observed cases, the supplementary motility in abduction in complete paralysis of the deltoid. He cites Bunts' report of nineteen cases of paralysis of the circumflex nerve, in seven of which function was recovered. In four of these, there was no deltoid power. Pollock points out the importance of the long head of the biceps and of the supraspinatus and infraspinatus muscles. In combined action with the coracobrachialis, these muscles may be able to abduct the arm 65 degrees. When the head of the bone is firmly fixed in the glenoid fossa by the subscapularis and the pectoralis major, the serratus magnus, trapezius, rhomboids and levator anguli scapulae may bring about fair abduction.

*Static Relations Between Foot and Knee in Paralyzed Legs*—In cases of total paralysis of the foot associated with paralysis of the quadriceps, Putti<sup>39</sup> has obtained a successful blocking of dorsal flexion of the foot at an angle of 110 degrees, by inserting a graft from the shaft of the tibia into the anterior part of the astragalus. The top of the graft is so placed as to impinge on the anterior margin of the tibia. In cases of instability of the subastragalar joints, he adds an arthrodesis between the astragalus and os calcis, and between the astragalus and scaphoid. He has performed the operation in six cases, all due to poliomyelitis, in children between 7 and 16 years of age. The period of observation following the operation varied from two years and four months to six months. The results to date of last observations, both clinically and from the roentgenograms, were gratifying.

[ED. NOTE—Discomfort from impingement following fractures in this region is common, and we see no reason why such discomfort should not obtain if the blocking was deliberately produced as is proposed in this operation.]

*Spastic Conditions. Intraperineural Neurotomy*—Nutter<sup>40</sup> considers that intraperineural neurotomy should be performed only in those cases that can be under the surgeon's care for several years, and in which spasm of the muscles is the chief cause of loss of function. This spasm may be limited to a few muscles and yet standing and walking be practically impossible, rendering the patient incapable of mingling with other children. Nutter outlines the technic and after-treatment which he employs.

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38 Pollock, L. J. *Accessory Muscle Movements in Deltoid Paralysis*, J. A. M. A. **79**: 526 (Aug. 12) 1922.

39 Putti. *Chir. de Org. di Mov.* April, 1922.

40 Nutter. *J. Bone & Joint Surg.* July, 1922, p. 453.

## ARTHRITIS

*Types of Chronic Arthritis*—Swaim<sup>41</sup> described three types of arthritis which he believes are distinct in their etiology and pathology, and in their clinical and roentgenologic manifestations. He employs Goldthwait's nomenclature, calling them infectious, atrophic and hypertrophic. The response to treatment differs in the different types, and he considers clinical data of value only when these types are studied as separate pathologic entities. The closest association between the internist and the orthopedic surgeon should exist in treatment. It should be the function of the internist to discover the cause and to arrest activity, the function of the orthopedic surgeon, to prevent and correct deformity and to preserve function. Normal body function and normal body mechanics are interdependent. Restoration of normal body mechanics may turn the scale favorably.

*The Second Great Type of Chronic Arthritis*—Ely<sup>42</sup> considers that sufficient evidence has been accumulated to indicate that the second great type of chronic arthritis is probably caused by a protozoon which almost invariably gains access to the system through the diseased bone at the roots of decayed teeth. Its prime characteristic is an aseptic necrosis in the marrow in the immediate vicinity of the joint. It is recognized roentgenologically by the presence of spurs or lipping at the lines of attachment of the capsule. It occurs about twice as often in men as in women. It is a disease of middle or late adult life, never occurring before the third decade. Up to the present time, the best results in the treatment have been the removal of the focus in the alveolar processes of the jaws.

*Amebiasis of Bones*—Kofoid and Swezy<sup>43</sup> examined material from the excised head of a femur, in the immediate neighborhood of the necrotic areas, close to the eburnated surface of the joint. The material was received from Ely's clinic, he having obtained it from a case belonging to his second great type of arthritis. Kofoid and Swezy found ameboid cells which they interpret as *Endameba dysenteriae* in the specimen. The question arises as to whether the ameba of the bone is that of the bowel (*Endameba dysenteriae*), or the ameba of the teeth and tonsils (*Endameba gingivalis*). From their critical morphologic studies, they incline to the view that the ameba of the bone is *Ameba dysenteriae* rather than *Ameba gingivalis*. They state that, in their experience, coexistence of infection by *Ameba dysenteriae* and chronic arthritis has been frequent. They believe that only a tentative conclusion can as yet be reached.

41 Swaim. J Bone & Joint Surg, July, 1922, p 426

42 Ely. California State J Med, Oct, 1922 p 329

43 Kofoid C A, and Swezy Olive. Amebiasis of Bones, J A M A 78 1602 (May 27) 1922

[ED NOTE—Swaim's classification has the advantage of being a working classification, but the disadvantage of being a mixed etiologic and pathologic one. Ely's classification of Type I and Type II has at least the merit of simplicity, though it cannot be said to be descriptive. We know that there are forms of chronic arthritis in which infection, local or remote, plays the most important etiologic rôle. These are so many and so varied that our present knowledge perhaps forbids an accurate pathologic classification. Nichols and Richardson, finding that in this type the synovial membrane changes consisting in villous formation came early, proposed the name of proliferative arthritis, and noting that ankylosis was the usual end-result, also spoke of the type as the ankylosing type. This type corresponds to Ely's Type I. Nichols and Richardson recognized that another distinct type existed, in which the early joint changes were represented by a fibrillation and degeneration of the cartilage, and that the terminal changes rarely resulted in bony ankylosis. They, therefore, speak of a degenerative or non-ankylosing type, which corresponds to Ely's Type II and Swaim's hypertrophic type. They could find no evidence clinically or pathologically of an infection in this type, agreeing with Swaim and disagreeing with Ely's latest opinion. Whether there is, as Swaim holds, a third distinct type, which Goldthwait, Swaim, and others, notably McCrae, call the atrophic type, the Editors are not certain, though undoubtedly there are many cases in which atrophic areas and bone destruction appear at the joint line very early, associated with vasomotor changes.]

Such changes may be produced with certainty in the bones of guinea-pigs fed on a scorbutic diet, as Dr. Percy Howe at the Forsyth Dental Infirmary has so well shown. These joints go on to ankylosis, but whether these changes are purely metabolic or chemical, or whether they are the direct result of bacterial infection made possible by the lowered joint and bone tissue resistance to bacterial body habitants, harmless under normal conditions, remains to be demonstrated. Certain it is, as Swaim says, that the internist and the orthopedic surgeon must labor together in the study of perhaps the most important chronic disease that exists, and must attack the problem from both the biochemical and the bacterial approaches, and from the vantage ground of improvement in body mechanics and restoration of function. We trust that Ely, working perhaps with such an eminent protozoologist as Kofoid, will continue his investigations as to the etiologic importance of *Amœba dysenteriae* or *Amœba gingivalis*.]

*Acute Articular Typhoid*—Thiroloux and Harmelin<sup>44</sup> report a case of acute multiple arthritis which developed shortly after injury to the

<sup>44</sup> Thiroloux and Harmelin. *Bull. et mem. Soc. med. d. hôp. de Paris*, July 7, 1922, p. 1054.

feet, in a young man Multiple hemorrhages occurred, and typhoid bacilli were discovered in the blood at the end of the third week Salicylates proved of no avail, and the exsanguinated patient died in two months

*Spondylitis Due to Leukemia*—Melchior <sup>45</sup> describes a case of a boy of 11, who complained of rather sudden onset of pain in the lumbar spine At examination two months later, rigidity and tenderness were found, and a diagnosis of tuberculous caries was made An Albee operation was performed, but an infection occurred and the graft was removed The blood showed a leukemia, and at necropsy, two months later, the fifth lumbar vertebra was found destroyed by lymphatic cells A lymphatic focus was also present in the femur One previous similar case was reported in the *Lancet* in 1914, page 173

*The Effect of Sodium Salicylate on the Development of Arthritis in Rabbits*—Boots and Swift <sup>46</sup> have carried out a series of experiments to determine whether sodium salicylate administered to rabbits by stomach tube in doses comparable to those given to patients with acute rheumatic fever would prevent arthritis in animals inoculated with cultures of *Streptococcus viridans* Fifty rabbits were studied Twenty-five were inoculated and twenty-five were used as controls Twenty-three developed arthritis, and the authors consider that this proves that salicylates do not prevent arthritis The animals receiving the salicylates, however, seemed from an analysis of the joint fluids to have a less severe arthritis than did the controls

*Sulphur Treatment of Chronic Arthritis*—Weskott's <sup>47</sup> experiences with the administration of sulphur in the treatment of chronic arthritis have not been so favorable as he had expected them to be from the reports of Meyer-Bisch and the French authors He encountered severe general reactions, such as vomiting and tremulousness, which persisted for several hours In many cases, there was little if any relief from pain in the affected joints

*Tonsillectomies for Rheumatism in Adults*—Hastings <sup>48</sup> has reviewed critically the results of 130 tonsillectomies performed on adults between 19 and 65 for the purpose of relieving rheumatic symptoms of pain and stiffness in the joints, requiring in some cases crutches and apparatus There were no cases of definite, well established "rheumatoid arthritis" and none of the patients were bedridden Previous throat trouble had

<sup>45</sup> Melchior Zentralbl f Chir Nov 25 1922, p 1737

<sup>46</sup> Boots R H, and Swift H F The Effects of Sodium Salicylate on the Development of Arthritis in Rabbits Inoculated with Streptococcus Viridans abstr J A M A 78 1922 (June 17) 1922

<sup>47</sup> Weskott Munchen Med Wchnschr 1922, No 18 p 674

<sup>48</sup> Hastings Ann Otol, Rhinol & Laryngol March 1922

existed in about 66 per cent of the cases. Sixty-nine cases were classed as mild chronic arthritis, twenty-eight, as moderate, and four, as severe, three, as acute arthritis, six, as neuritis, and twenty as myalgia.

Of these 130 patients, Hastings considered from observation and reports that forty, or about 30 per cent, were cured, fourteen, or about 9 per cent, were greatly improved and twenty-four, or 19 per cent, not improved. In twenty-nine cases, the results could not be traced.

*Absorption from Joints*—S. Draganesco and A. L. Draganesco<sup>49</sup> have studied the absorptive power of joints by injecting various drugs, such as potassium iodid and methylene blue, into diseased joints, and examining the urine thereafter. They also injected the drugs subcutaneously and examined the joint fluids. They conclude that joints possess considerable absorbing power for fluids injected directly into them but not for drugs injected elsewhere in the body subcutaneously.

#### NEOPLASMS

*Pathologic Fractures*—Codman,<sup>50</sup> in an interesting short paper read before the Clinical Congress, American College of Surgeons, makes the following chief points regarding pathologic fractures: 1. Fracture is the symptom of onset in a central lesion suggests bone cyst, and if the patient is 15 years of age or younger, it may be looked on as almost pathognomonic (Bloodgood). 2. Pathologic fractures are usually transverse, with little tendency to displacement. They are liable to be bendings, bowings, bucklings, telescopings, and impactions. 3. A safe surgical nomenclature of bone tumors is the following: (a) osteitis fibrosa, which includes ordinary bone cysts and the hemorrhagic osteomyelitis of Barrie, (b) Bloodgood's giant cell tumor, called myeloma in Canada and Europe, which may prove malignant, (c) giant cell sarcoma—an epulis-like tumor with "foreign body giant cells"—which eventually proves malignant, (d) true osteogenetic sarcoma, either central or periosteal, (e) metastatic new growths, cancer, hypernephroma, etc., (f) multiple myeloma, with or without albuminuria, (g) tumors of tissues which normally occur in bone as well as in other parts of the body, such as nerves, vessels and fat, causing bone destruction and proliferation secondarily (fortunately rare), (h) tumors too common and well understood to be included, e. g., chondroma, osteoma, and lesions of syphilis and tuberculosis, (i) tumors too rare and little understood to be taken into practical consideration, e. g., the tumors of the specific marrow cells. 4. Fractures due to benign bone tumors and other pathologic conditions, excluding new growths, usually unite

<sup>49</sup> Draganesco, S., and Draganesco, A. L. *Presse med.*, Aug. 30, 1922, p. 1368.

<sup>50</sup> Codman. *Surg., Gynec. & Obst.*, May, 1922.

Those due to carcinoma and other metastases rarely unite 5 Judging from the material accumulated by the Registry of Bone Sarcoma, it should be a general rule to employ splints in all cases of tumors of the long bones as soon as they are observed, particularly those of the humerus and femur, which are not supported by companion bones Pathologic fracture occurred in 14 per cent of 200 supposed cases of sarcomas of the long bones Of nineteen humeral cases, it occurred in 47 per cent, of the 102 femur cases, in 15 per cent, and of the seventy-nine cases of the four self-splinting bones, in only 5 per cent 6 As regards fracture as a cause of sarcoma, exuberant callus resembles true sarcoma and perhaps the cause will be found to be a negative rather than a positive one, such as the removal of an inhibition in the process of repair On this theory, malignancy would be an unbridled repair process

*Hemorrhagic Osteomyelitis*—Barrie<sup>51</sup> has personally observed forty-two cases of what he terms hemorrhagic osteomyelitis The age incidence was from 18 months to 63 years Seventy-five per cent of these solitary lesions had, according to Barrie, a traumatic etiology Bacteria were never isolated in any of the removed tissue The lesion occurred in the lower extremity three times as often as in the upper extremity, in the femur most frequently, and next in the tibia Pressure always revealed tenderness and elicited pain Signs of inflammation were lacking The dominant pathologic picture is that of highly vascular granulation tissue filling a bone cavity There may be localized fibrous metaplastic areas and numerous scattered hyaline bodies in and around the hemorrhagic mass Scavenger giant cells may be many or few, but true tumor giant cells are never found in these lesions A preoperative diagnosis without a roentgenogram is impossible There is usually in the early lesions a clear-cut, rounded or oval spot on the cortex Expansion of the bone is observed without breaking through the periosteum Any chronic bone lesion which has broken through the periosteum should be regarded with suspicion as to malignancy unless the lesion is known to be definitely suppurative The treatment consists of removing all exuberant granulations and thoroughly curetting the bone cavity wall Swabbing out with tincture of iodine may stimulate normal bone production If hemorrhage is severe, packing for forty-eight hours may be necessary The healing of large cavities is promoted by filling with bone graft shavings or chips

*Sarcoma of Bone*—Gibbon<sup>52</sup> describes a lesion in the lower end of the femur which, from the roentgenogram was diagnosed as a new growth and at operation was thought to be a giant cell tumor Micro-

51 Barrie I Bone & Joint Surg Oct 1922 p 653

52 Gibbon I Bone & Joint Surg July 1922 p 512

scopically, it proved to be a large round cell sarcoma with a few giant cells. The growth was removed as completely as possible, amputation being refused. Recurrence in three weeks necessitated a second operation, and four weeks later amputation was necessary. The case is of interest as occurring in a 16 year old boy, and because both roentgenographically and in gross specimen it closely resembled a giant cell growth. The author urges the importance of accurate microscopic diagnosis.

*Total Removal of the Scapula for Primary Giant Cell Sarcoma*—Davis<sup>53</sup> reports the occurrence of a tumor of the scapula necessitating total excision, in a patient, aged 24. The tumor proved on pathologic examination to be a large giant cell sarcoma. Ten weeks following the operation, the patient reported by letter that she was doing general house work without difficulty and was able to make beds, wash dishes, sweep, dust and iron, and comb her own hair. The operation was performed as follows. An incision was made over the tip of the coracoid, extending outward along the coracobrachialis. The tip of the coracoid was exposed, and the attachments of the pectoralis minor, coracobrachialis and short head of the biceps were divided. The subscapular artery and vein were freed and ligated. An incision was then made from the superior angle of the scapula along the vertebral border to the lower angle, and this was connected with another incision extending from the tip of the acromion along the spine of the scapula. The muscles attached to the scapula were divided in the following order: trapezius, the rhomboids, latissimus dorsi and teres major and minor. The serratus magnus was cut just as it passed under the external border of the subscapularis. The lower angle of the scapula was then elevated and the remaining muscles, consisting of the levator anguli scapuli, omohyoid and deltoid, were cut as they came into view. The descending branches of the transverse colic and the transverse scapular arteries were cut and tied. The acromion was then disarticulated from the clavicle, and the shoulder joint was opened posteriorly. The long head of the biceps and the triceps attachment were divided, and the glenoid process was removed from its connection with the humerus. A running suture was employed to gather together the mass of muscles and form a muscular pocket about the head of the humerus. The wound was closed with drainage, and the arm was dressed in slight abduction by means of a thick axillary pad.

*Prevalence of Bone Sarcoma in Massachusetts*—Codman<sup>54</sup> makes a further report of the progress of the Registry of Bone Sarcoma. In

53 Davis Surg, Gynec & Obst, June, 1922

54 Codman Boston M & S J, Oct 12, 1922, p 543

a previous article, seventy-one living persons presenting possible cases had been located in Massachusetts. Further investigation has reduced this number to nine. If giant cell tumors should be included, there would be at least twenty-two more. Four practical points have been thus far brought out: 1. The diagnosis should be made with great caution. 2. Bloodgood's claim as to the benign character of giant cell tumors is confirmed by the experience in Massachusetts. 3. True osteogenetic sarcoma is almost always fatal, the rare exceptions occurring in cases in which amputation is performed. 4. Since only nine persons having bone sarcoma (excluding the giant cell tumors) can be located in a population of approximately 4,000,000, there are probably only 225 in the United States. Codman urges the importance of registering persons who refuse operation but are treated with roentgen rays, radium, Coley's serum, etc.

*Roentgen-Ray Diagnosis of Tumors of Long Bones*—Nichols,<sup>55</sup> in an endeavor to simplify the roentgenologic diagnosis of bone tumors, suggests a differential method based on the observation of four fundamental points: (1) their origin, whether medullary or cortical, (2) whether or not they are characterized by bone production, by bone destruction, or both, (3) the resultant condition of the cortex, whether expanded or destroyed, and (4) whether the growth is invasive or non-invasive. His classification of tumors is presented in the accompanying table.

## CLASSIFICATION OF TUMORS

1 Origin		
a Medullary	$\left\{ \begin{array}{l} \text{Sarcoma} \\ \text{Carcinoma} \\ \text{Hypernephroma} \\ \text{Myeloma} \end{array} \right\}$	$\left\{ \begin{array}{l} \text{Fibroma} \\ \text{Bone cyst} \\ \text{Enchondroma} \\ \text{Giant cell sarcoma} \end{array} \right\}$
b Cortical	$\left\{ \begin{array}{l} \text{Periosteal sarcoma} \\ \text{Osteosarcoma} \\ \text{Osteoma} \\ \text{Enchondroma} \end{array} \right\}$	$\left\{ \begin{array}{l} \text{Ossifying hematoma} \\ \text{Myositis ossificans} \\ \text{Bone cyst (rare)} \\ \text{Exostoses} \end{array} \right\}$
2 Bone Production	$\left\{ \begin{array}{l} \text{Periosteal sarcoma} \\ \text{Osteosarcoma} \\ \text{Osteoma} \\ \text{Exostoses} \end{array} \right\}$	$\left\{ \begin{array}{l} \text{Ossifying hematoma} \\ \text{Myositis ossificans} \\ \text{Enchondroma} \\ \text{Bone cyst after fracture} \end{array} \right\}$
3 Condition of Cortex		
a Expanded	$\left\{ \begin{array}{l} \text{Enchondroma} \\ \text{Bone cyst} \end{array} \right\}$	$\left\{ \begin{array}{l} \text{Giant cell sarcoma} \\ \text{Fibroma} \end{array} \right\}$
b Destroyed	$\left\{ \begin{array}{l} \text{Sarcoma} \\ \text{Carcinoma} \end{array} \right\}$	$\left\{ \begin{array}{l} \text{Hypernephroma} \\ \text{Myeloma} \\ \text{Periosteal sarcoma} \end{array} \right\}$
4 Invasion		
a Invasive	All malignant tumors	
b Noninvasive	All benign tumors	

<sup>55</sup> Nichols Surg., Gynec. & Obst., Sept., 1922, p. 301



*Tumors of Bone*—Bloodgood<sup>56</sup> suggests the following working rule for the diagnosis and treatment of tumors of bone. If a patient is under 15 years, we can exclude sarcoma, and the diagnosis rests between the common bone cyst, the less frequent giant cell tumor and the rare chondromyxoma. If the patient is over 15, sarcoma cannot be excluded. The most common central lesion of bone is the benign bone cyst. In the majority of cases, they recover without any treatment. The second is the giant cell tumor, which predominates in patients over 15. Myxoma may occur at any age from birth to death. Myxoma must be constantly borne in mind, and is the most difficult of all bone tumors to eradicate locally.

The location of the tumor is also important, whether in the end of the bone, in the joint, or in the middle of the bone near the nutrient foramen, the last being the favorite site of the metastasizing carcinoma. Malignant tumors do not cross a joint, so that a lesion involving both sides of the joint is always a benign process. Whether the tumor is single or multiple, is also important, as is also the age of the patient.

[ED. NOTE—Differential diagnosis of bone tumors is far from certain by any known method, particularly roentgenoscopy. This is altogether natural when we remember that even with the gross specimen before him and the slide under the microscope, the pathologist is often uncertain as to its character. Often there is such widespread involvement of the bone that it is impossible to determine the point of origin or the invasion. While in sympathy with any effort to systematize the diagnosis, we are under the impression that the one point of importance is whether the growth is benign or malignant, and that the best way to determine this is by immediate exploration and pathologic examination. The relation of the region to be examined is also of importance, and occasionally the surgeon well trained in gross appearances in malignant disease must be governed by his finding quite as much as by the report of the pathologist, made necessarily somewhat incompletely at the time of operation.]

*Fibrous Tumor of the Foot*—Thorek<sup>57</sup> reports two unusual cases of large benign fibrous tumors of the foot, one originating near the internal malleolus and the other in the plantar fascia. Both were widely excised, and the skin defect was closed at a later stage by whole thickness grafts. A review of the literature reveals the extreme rarity of this type of growth, the majority of such tumors being malignant.

*Carcinoma of the Vertebrae*—Sicard<sup>58</sup> calls attention to the differential diagnosis between cancer of the spine and tuberculous caries by

56 Bloodgood Northwest Med, Sept, 1922

57 Thorek Ann Surg, July, 1922

58 Sicard Bull et mem Soc med d hop de Paris, June 16, 1922, p 920

means of roentgenograms. The condition of the intervertebral disk he considers indicative. In Pott's disease, the disk is early affected or destroyed, while in carcinoma it is comparatively intact and the body is chiefly affected. He considers that the explanation of this lack of disk involvement in cancer may be found in the poor blood supply of the disk, while the metastasizing cells are planted in the bodies of the vertebrae by their richer circulation.

*Bone Metastasis from Primary Carcinoma of the Urinary Bladder* — Wells,<sup>59</sup> in five cases of cancer of the urinary bladder, in which necropsy was performed, found only one with bone metastasis. The main tumor was in the sternum, in several of the ribs and in the ilium. There had been no symptoms referable to the bladder in this case.

#### OSTEOMYELITIS

*Regeneration of Shaft of Humerus Following Acute Osteomyelitis* — Nifong<sup>60</sup> reports a case of complete regeneration of the shaft of the humerus in a child of 12, in which there had been destruction en masse, so that the sequestrum represented all the shaft except the articular ends. The periosteum with barely palpable flakes of bone represented the involucrum. No transplant was employed, but the periosteum was sutured together. Complete reformation of the humerus occurred after twenty-three months, and motion was only a little short of normal.

*An Analysis of One Hundred and Sixty Cases of Osteomyelitis, with End-Results* — Speed,<sup>61</sup> for purposes of report and study, divides osteomyelitis into four types: acute localized, chronic localized, acute diffuse and chronic diffuse. Twenty-nine of his 160 cases were localized and 131 diffuse. Eighty per cent of the diffuse type occurred before the age of 15. Those of localized type were cured by thorough curettage and removal of the localized disease. In the acute diffuse type, twenty-one cases, there was a definite history of trauma in 55 per cent. In this group, there were four cases showing multiple lesions. A conservative, trap door, simple drainage of the bone was established as soon as the diagnosis was made. For purposes of this report the author considers a patient cured when no symptoms have been evident for at least a year. There were nine apparently complete cures, five incomplete cures and seven deaths. The high mortality is accounted for by the fact that several of the patients were in a desperate condition when brought to the hospital. There were 110 cases of the chronic diffuse type. The average number of operations performed in each case was three. Ten per cent of the lesions had been healed for vary-

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<sup>59</sup> Wells. J. Urol. May, 1922.

<sup>60</sup> Nifong. Missouri State M. A. J., May, 1922.

<sup>61</sup> Speed. Southern M. J. Sept., 1922. p. 721.

ing periods of from six months to fifteen years, at various times, before the recurrence which brought them to the hospital. Of the sixty-four persons operated on, one died of sepsis, 14 per cent were still undergoing drainage and 84 per cent were cured, or at least had remained without symptoms for at least one year. The records of this series do not favor complete subperiosteal resection of the tibia, radius or ulna, even when practically the entire shaft is involved. Any loss of continuity of bone is to be avoided. Defects of only a half inch cause a marked prolongation of the period of disability. Simple fractures through the involucrum have all united much like normal bone.

*Chronic Bone Abscess*—Brickner,<sup>62</sup> proceeding on the theory that in chronic bone abscess of afebrile character the infective organism has either been entirely destroyed or at least greatly attenuated in virulence, advocates the treatment of such cases by conservative rather than by radical surgical procedures. His procedure consists in exposing the bone through a small incision and driving a drill, one-fourth inch in diameter, through the cortex into the pus cavity. With the escape of pus, the drill is removed and nothing else is introduced into the bone. A culture is made to determine what, if any, living organisms are present, and a smear is also made and examined at once. If, instead of none or a few bacteria, many are found, the procedure may be altered. A small drain of folded rubber dam is laid in the soft parts, down to but not into the bone opening, and the wound is closed. The author has used this method in selected cases for several years, with relief of pain and without recurrence of symptoms.

[ED. NOTE.—We have been impressed with the fact, as pointed out in previous reports, that there is need for greater conservatism in the treatment of chronic osteomyelitis, and this is substantiated by Brickner's observations. At the same time, it must be admitted that no conclusions as to the end-results of treatment in cases of osteomyelitis are possible until the lapse of many years, and opinions as to the value of this particular method should not be formed until the case reports and end-results are published.]

#### BONE, JOINT AND TENDON SURGERY

*Beef Bone Pegs*—Tarnowsky<sup>63</sup> has employed a beef-bone intramedullary peg in fifteen cases of recent fractures, for internal fixation, and in two cases of ununited fracture of the neck of the femur, with success in all but one case. Union occurred and the bone was well tolerated. He considers the fate of these heterogenous grafts to be dependent on the following considerations: 1. With the proliferation of new

<sup>62</sup> Brickner. J. Gynec. & Obst., July, 1922.

<sup>63</sup> Tarnowsky. Surg. Gynec. & Obst., Sept., 1922, p. 342.

cells from the living proximal and distal ends of the fractured bone keeping pace with absorption of dead cells from the graft, complete disappearance of the latter coincides with complete union of the fracture 2 With hyperactive new cell formation and sluggish absorption, the graft constitutes a sequestrum which either eburnates and remains in a state of quiescence, or may act as an irritant foreign body, with sinus formation 3 With hyperactive bone absorption and sluggish new bone formation, the graft disappears by combined extrusion and absorption before union takes place

Girode,<sup>64</sup> on the other hand, in Delbet's clinic, has had a most unfavorable experience with beef bone implants in fifteen cases of pseudarthrosis or fracture of the neck of the femur The bone was obtained from the tibia or ulna of freshly slaughtered cattle and preserved in alcohol Delbet has abandoned the method

*Beef Bone in Stabilizing Operations on the Spine*—Brown<sup>65</sup> has employed boiled beef bone, cut from the rib, carefully sterilized by boiling, and inserted after the manner of an Albee graft into the split spinous processes He reports results in thirty-three adult patients and one child Twenty-nine were operated on for tuberculosis of the spine, four for old fractures, and one, an adult, for an unstable spine following poliomyelitis It was demonstrated that the beef bone was tolerated by the body for as long as four and one-half years without any sign of irritation or inflammation and only slight indications of absorption The end-results in this series and in experimental work on dogs leads the author to feel that immobilization of the spine can be more surely accomplished by fusion of the laminae and articular facets than by means of a beef-bone splint inserted between the spinous processes, even if the laminae and articular facets are fused on one side, in addition In the cases of tuberculosis of the spine in adults, a careful investigation revealed the fact that half of the cases had more than one focus of tuberculous infection, and in six there were two separate foci in the spine

[ED NOTE—This rather extensive and careful work of Brown is of value and seems to the editors to indicate that surgeons will probably be disappointed if they depend on boiled beef bone to act more than temporarily as a nonirritating internal splint In several of Brown's cases, it was possible to reexamine the splint when a second operation was performed for a later developing second focus, and in one case in which the graft was broken from excessive lifting Although the beef bone was found to have been perfectly tolerated it showed little sign of actual fusion with the spinous processes and was in places

64 Girode Rev de chir, 60 60 1922

65 Brown J Bone & Joint Surg Oct 1922 p 711

lying free in a tube of bone, the tips of the spinous process having united over it, but not with it. In other places, absorption was slowly taking place. In the light of these studies, it seems to us that the procedure which Kleinberg<sup>66</sup> has employed in stabilizing scoliotic spines is not likely to accomplish its purpose. This consists, in addition to a fusion operation, of implanting a long beef bone splint on the concave side of the curve into two spinous processes above and below, which have no intimate contact with denuded bone over a considerable span. We doubt the permanent efficiency of this supporting strut.]

*Transplantation of the Fibula*—MacAusland and Sargent<sup>67</sup> report successful cases of transplantation of the fibula to replace the loss of the entire shaft of the tibia following osteomyelitis. The upper and lower ends of the bone were transplanted at different periods in order to preserve the blood supply. Hypertrophy of the fibula resulted, with normal function of the ankle joint and no instability.

*Para-Articular Arthrodesis of the Hip Joint*—Kappis<sup>68</sup> has immobilized the hip joint in fourteen cases of old tuberculous coxitis by implanting a heavy bone and periosteal graft between the trochanter and the iliac crest. He considers that the results justify the extensive use of this method.

Nove-Josserand<sup>69</sup> also, in discussing the indications for the different methods of surgical fixation of a joint, comments on Maragliano's<sup>70</sup> success with a long bone graft similar to the graft employed by Kappis. These grafts retained their vitality, although contacted only at their two ends. He points out that this procedure runs no risk of lighting up the old tuberculous process. The results he considers most satisfactory. He prophesies a brilliant future for the method.

[ED. NOTE—This procedure would in no way correct existing deformity, which is often one of the main reasons for attempting an arthrodesis. We have rarely if ever met a recurrence of the old disease after a well-executed arthrodesis, and we should also doubt the permanence in many cases of this graft, contacted, as it must be, with such a thin bone as the ilium.]

*Resection of the Knee in Children*—Nussbaum<sup>71</sup> has reviewed the excellent records of Garre in regard to the end-results of resection of the knee joint in children. Shortening was the most important finding, the amount bearing some relation to the age of the child, as was

66 Kleinberg. New York M. J., July 19, 1922, p. 93.

67 MacAusland and Sargent. Ann. Surg., July, 1922.

68 Kappis. Deutsch. Ztschr. f. Chir., March, 1922, p. 316.

69 Nove-Josserand. Paris med., July 15, 1922.

70 Maragliano. Paris med., May 20, 1922, p. 1579.

71 Nussbaum. Beitr. z. klin. Chir. 126:662, 1922.

to be expected. When the epiphyseal lines were left undisturbed, the shortening was less marked, but in many cases even thus conservatively treated, it was considerable. Another important fact was the participation of the foot in the disturbance of development, the cavus deformity which ensued being noticeable. A subsequent flexion of the knee developed in several cases. The course of the disease was undoubtedly shortened in many cases, and Nussbaum considers that there may be social indications for the operation.

*A New Approach for Ankylosis of the Jaw*—Beckenheimer<sup>72</sup> proposes a new approach to the temporomaxillary articulation for an arthroplastic operation in cases of ankylosis. A vertical incision is made just behind the auricle, avoiding above the vessels to the outer portion of the ear and not extending low enough to reach the facial nerve. The auricle is turned forward, and the external meatus divided. He states that the exposure of the joint is excellent, and the method has the great advantage of safety as far as the facial nerve and the parotid gland are concerned. The condyle is resected and a fascial flap interposed. The auricle is carefully stitched in place and a drain placed in the meatus. The scar is unnoticeable.

*Arthroplasty*—Putti<sup>73</sup> has on record 113 cases of operative mobilization of stiffened joints: forty of the knee, thirty-eight of the elbow, seventeen of the hip and ten of the jaws. He considers that the greatest advance which has been made in the operation is the interposition of the free fascial transplant. His general principles embody a free exposure of the joint, cutting as few as possible of the structures which induce motion and are essential to weightbearing. He covers both ends of the bone with free fascial flaps. He never drains the new joint and lays great stress on traction on the distal segment. This he maintains for a month. Passive movements carried out by the patient himself, by means of a simple suspension apparatus, are begun on the tenth day. When complete healing has taken place, hot-air treatment is begun, which is continued each day for several months. Putti considers that stimulation of the muscles by electricity is more efficient than massage. Weightbearing is allowed in thirty days, aided by a simple mechanical apparatus. This is a critical period, and the joint may be stiff and a little painful. Care must be taken at this period not to push the hot-air treatment too far and it may be best to suspend it for a few days and cautiously resume it. He considers that success is most likely in elbow operations, knee, jaw and hip operations following in the order given.

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72 Beckenheimer. *Deutsch med Wchnschr.* June 2, 1922, p. 729.

73 Putti. *Lyons chir.* March-April, 1922, p. 590.

Roeren,<sup>74</sup> in an article on mobilization of the ankylosed knee joint, describes his technic and emphasizes the importance of stimulating and developing the extensor muscles in every way before the operation, and of exerting traction after the operation. He fashions the femoral condyles like a roller and then makes concave the upper end of the tibia, implanting a flap of fat tissue extending between the ends and up beneath the mobilized patella. His results make him feel that the indications for the operation are even wider than Payr suggests in his latest papers. His contraindications are extensive injury to the extensor apparatus. He considers that the prognosis in cases in which the ankylosis is due to purulent infection must always be doubtful.

*Volkman's Ischemic Contraction*—Soubeyran<sup>75</sup> reports an excellent result, in a boy of 10 suffering from this crippling affection, by resection of 2 cm. of the radius and ulna. The bone was removed subperiosteally at different levels in the two bones, the sutured periosteal cuff retaining the position. The plaster fixation held the elbow flexed, the hand in supination, and the fingers fully extended. The fixation was retained for twenty-five days, and function then resumed. The case has been followed for eight years, and function remains complete, with eventual shortening of the arm of 15 cm.

*Wavelike Incisions for Contractures*—Ritschl<sup>76</sup> has employed a wavelike incision in the skin to avoid secondary contractions of the scar in operations for the relief of joint contractures, such as tenotomy of the hamstrings and Dupuytren's contracture. The scar permits stretching as does a spiral spring, and crosses and recrosses the contracted deep structures at single points, thus minimizing the danger of adhesion between skin and tendon.

*Tendon Transplantation for Musculospiral (Radial) Nerve Injury*—Billington<sup>77</sup> has always obtained greatly improved function in his cases of muscle transplantation for this lack of musculospiral innervation, and he feels reasonably sure, with an intelligent patient and a favorable condition of the tissues, of securing a functional result closely approaching that of a normal hand. He employs a technic slightly different from that of Jones, McMurray and Starr. The pronator radii teres is sutured to the extensor carpi radialis longior and brevior, the flexor carpi ulnaris to the extensor minimi digiti, and the extensor communis digitorum and the flexor carpi radialis to the three extensor tendons of the thumb. He believes the index finger functions without a suture to its special tendon, and that he secures more perfect thumb

74 Roeren Arch f Ortho - u Unfall - Chir 20 36, 1922

75 Soubeyran Paris med, June 10, 1922, p 490

76 Ritschl Munchen med Wchnschr, 1922 No 2, p 397

77 Billington J Bone & Joint Surg, July 1922, p 538

function if the extensor longus pollicis is included. He is careful to cover his sutures with fascia. The application, immediately following the operation, of a specially molded, accurately fitting long cockup splint with thumb piece, which will positively maintain the proper attitude of the fingers and thumb, he considers essential in the after-treatment, as is also patient reeducation of the muscles and physiotherapy, for a period of two or three months.

*Postoperative Care of Flexion Contraction of the Hip*—Stewart<sup>78</sup> has devised a simple and practical method of maintaining adequate hyperextension of the hip after Soutter's operation of fasciotomy, by means of an adjustable wooden or metal frame. He justly emphasizes the importance of after-care in these cases, which are likely to develop unfortunate complications due to nerve stretching or circulatory disturbances.

[ED. NOTE—The editors have employed this frame with much satisfaction.]

*Repair of Tendons in Fingers*—Bunnell,<sup>79</sup> in a carefully prepared article, discusses the repair of old tendon injuries of the fingers and hand, illustrating it by reports of difficult personal cases, with convincing photographic records. The points which he considers fundamental in the technic are the atraumatic handling of the tendons and the reconstruction of the gliding mechanism. In repairing an old injury of a flexor tendon of the finger, it is not practical to suture the tendon in the finger, because the sheath has been obliterated and there is not sufficient room to surround the suture line with a free fat graft thick enough to allow motion. When the suture line pulls over two joints, it is necessary to remove entirely the damaged tendon from the finger and to replace it with a free tendon graft. The suturing of the tendon can then be done at its insertion, and in the palm or forearm, where adhesions will do less harm. When the sheath has been obliterated, it is necessary to transplant not only the tendon, but also its gliding mechanism, either sheath or paratenon. The repair of both sublimis and profundus tendon is too difficult, and it is sufficient to replace the latter only and sacrifice the former. Function is necessary to keep a tendon graft in good condition. Grafts may be obtained from the sublimis tendon, the palmaris longus, the long extensors of the toes (a branched tendon), tubularized triceps, fascia lata, etc. The suturing of the tendon must be very strong in order to permit the all important postoperative exercises and for this purpose the author has found it very advantageous to employ a special clamp for holding the tendon.

<sup>78</sup> Stewart. J. Bone & Joint Surg., July 1922, p. 548.

<sup>79</sup> Bunnell. Surg. Gynec. & Obst. July 1922.



and guiding the quilting sutures. It is difficult to remove a tendon neatly from a mass of adhesions, and especially from beneath the annular ligament and from within a finger, and for this purpose he has devised a special stripper. For placing a tendon with its paratenon through a tunnel in the finger, he uses a special type of flexible probe, with expanded middle and funnel-shaped rear end to carry the tendon. Quite often after a tendon repair or an infection or general traumatism, it is necessary to plane off the adhesions by the use of the tendon stripper, with immediate active movement following. Longitudinal incisions in the palm and the flexor aspects of the fingers should be avoided. Transverse incisions in the palm and lateral incisions in the fingers are better. Postoperative immobilization should not be employed. For a flexor tendon, the wrist may be strongly flexed and held by a check rein of adhesive plaster running up and around the forearm, robbing the muscles pulling against the tendon which has been operated on of their power to exert too much traction, but allowing active movement. This may be maintained for five weeks, until union is solid. Cooperation by the patient is essential, and he must be willing to undergo some punishment to obtain a good result. The prognosis should be guarded, but it is usually possible to restore from 80 to 95 per cent of lost function.

[ED. NOTE—All who have attempted the repair of old injuries of the tendons of the fingers have been impressed by the great difficulties in the way of obtaining good functional results. Bunnell has been working on this problem for five years. He has elaborated a plan of operation and a technic which are logical and have produced unusually good results. The specially devised instruments are ingenious and seem to serve a useful purpose. The article is difficult to abstract fully and we commend its perusal and study to all those called on to treat these difficult cases.]

#### PERIPHERAL NERVES

*Late Affections of Ulnar Nerve Following Old Fractures*—Lusena<sup>80</sup> reviews the literature and reports two cases of ulnar paralysis developing eight and eighteen years, respectively, after a fracture of the humerus. Fractures of the capitellum resulting in a valgus position of the arm seem most likely to be followed by this affection of the nerve. This is probably because extra tension is brought on the nerve (perhaps by growth), or the groove is so altered that the nerve is exposed to injuries. Electricity, massage, the use of protective apparatus and operative transposition of the nerve have been tried with varying results.

<sup>80</sup> Lusena. *Chir de Org di Mov*, April, 1922.

[ED NOTE—One of the Editors has operated in three such cases, all following fracture of the external condyle. In all cases, the nerve has been transposed to the front of the joint. In two of the cases, the paralysis occurred in adult life following fractures in childhood, in the third, it came on between two and three years after the fracture. In one case, nearly complete restoration of function took place, in the second, great improvement followed the operation, and in the third no change has thus far resulted.]

*Direct Stimulation of Peripheral Nerves*—Feiss,<sup>81</sup> from his experience with surgical repair of nerve injuries in several hundred cases at the American Ambulance, is convinced of the value of direct stimulation of the exposed nerve at the time of operation, in determining the procedure to be employed and the degree of injury to conduction. Many possibilities of technical error exist in the use of the method, and he formulates rules for their avoidance.

- 1 The nerve should be freed for a considerable distance to give free access, but care should be taken to avoid unnecessary exposure, in order not to injure the circulation of the nerve sheath.
- 2 The effects of mechanical stimulation during the freeing of the nerve should be carefully observed.
- 3 Before faradic stimulation, the nerve should be isolated by lifting it on a nonconductor hook, preferably of glass.
- 4 The nerve should be moistened constantly, but it should not lie in a saline bath, as this may cause spread of the current.
- 5 Bipolar electrodes are preferable to unipolar ones. The platinum points should be long enough to permit their relative positions to be altered by bending.
- 6 Such a current as would be just perceptible when applied to the tip of the tongue should be employed, beginning with a current of moderate strength.
- 7 Stimulation should be exerted on all sides of the nerve, but if there is a neuroma, the proximal segment is the important part in an efferent nerve, and the distal segment in an afferent nerve.
- 8 If a positive response is obtained, the nerve should be separated into its constituent bundles and tested individually.
- 9 The precise nature of the responses should be noted.
- 10 Different nerves respond in various ways to different frequency of current interruptions. Slow interruptions should be the rule in the beginning, increasing as necessary.
- 11 If it is decided to excise the neuroma, the motor response to the direct mechanical stimulation during the procedure should be observed. The entire distal portion of the limb should be sterilized, along with the operative field. This should be left undraped in order that the various phenomena following stimulation may be observed.

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<sup>81</sup> Feiss. Surg., Gynec. & Obst. June 1922 p. 243

## DISLOCATIONS

*Retrosternal Dislocation of the Clavicle*—Schlegel<sup>82</sup> describes a very rare case of retrosternal dislocation of the clavicle. He states that only twenty cases have been reported. The right clavicle was displaced 4 cm behind the sternum, causing symptoms of pressure on the innominate artery. Replacement was impossible, and a resection of the displaced end, 3 cm in length, was performed, with an excellent functional result.

Anderson<sup>83</sup> reports a dislocation of the fourth cervical on the fifth, the fourth body overlapping the fifth by 2 cm. There were no symptoms of cord pressure. The case was seen twenty days after the accident, a fall backward on the head. Reduction was attempted by traction of 20 pounds, and manipulation under ether, but failed. A plaster cast and a head support were applied, and good function was assured one year after the accident. The roentgenogram at this time showed ankylosis and partial absorption of the fourth cervical.

*Lateral Dislocation of the Lumbar Vertebrae*—Hartley<sup>84</sup> describes an unusual traumatic dislocation of the first lumbar vertebra to the left of the second, in a man of 38, caused by a heavy stone falling on his back. The patient was operated on by Sir Harold Stiles. By forced flexion, the spinous processes were separated and the articular processes cleared from one another. The dislocation was then reduced. As there had been ligamentous tearing, an arthrodesis of the articular processes was performed. Simple dislocations of the lumbar spine are very rare, because in forced flexion the cancellous bone of the bodies yields more readily than ligaments of the spinous processes and neural arches. The only other case reported of lateral dislocation of the lumbar spine without fracture was that of Charles Bill in 1824. Exposure of the neural arches and articular processes undoubtedly facilitates reduction, and it is suggested that open operation will prove of value in reduction of spinal dislocations of the more common types.

Constantini and Duboucher<sup>85</sup> report a luxation of the second lumbar vertebra to the right and forward on the third lumbar, with complete paraplegia. Reduction, which was not obtained by traction in the Sayre suspension method nor by manipulation under ether, was secured by open operation. The authors state that this was not difficult. They recommend this procedure, as does Hartley in the article reviewed above. No improvement in the paraplegia resulted.

82 Schlegel. *Munchen med Wchnschr*, 1922, No 14, p 511

83 Anderson. *Northwest Med*, July, 1922

84 Hartley. *Edinburgh M J*, July, 1922

85 Constantini and Duboucher. *Rev d'orthop*, Jan, 1922, p 27

*Traumatic Dislocation of the Hip in Children*—Doelle<sup>86</sup> has encountered two cases of traumatic dislocation in children. He finds only thirty-eight cases reported in the literature. Twenty were of the iliac type, six of the obturator, three sciatic, two suprapubic and six not specified. The mechanism of the injury, the diagnosis and treatment differed in no way from those in dislocations in adults.

Roello<sup>87</sup> also reports two cases in children of 6. These were ischiatic dislocations, one of which became spontaneously iliac after rest in bed for a few days on account of the child's condition. Roello considers that the ischiatic dislocation, from the nature of the ordinary injury, is probably commonly primary, and the iliac position secondary.

*Dislocation of the Knee*—Meadows<sup>88</sup> easily reduced a complete forward dislocation of the tibia on the femur in a man of 40, under ether, by traction on the semiflexed leg and backward pressure on the tibia. The patient insisted on leaving the hospital on the second day, wearing an elastic bandage. He returned to work on the twentieth day.

The 1921 Report of the U. S. Department of Labor and Industry tabulates fourteen cases of dislocation of the knee, with an average temporary disability of 25.1 days, and an average partial disability of 83.5 days. For this year, the dislocations of the knee represented 16 per cent of all dislocations.

*Recurrent Dislocation of the Patella*—MacAusland and Sargent<sup>89</sup> present a well illustrated article on recurrent dislocation of the patella, on the basis of sixteen cases treated by various operative methods. In two cases, conservative methods were tried, but eventually operation was necessary. In two, the operation of capsulorrhaphy was performed, in one of which it was a failure. The other was not traced. Eight were treated by the operative procedure of Goldthwait, and four by a slight modification of the method, with only one recurrence, later relieved by a correction of a rotation deformity of the femur following a supracondylar osteotomy. The authors give a reference to Goldthwait's article, but do not refer to the method as his. As originally described, this method consists of splitting the infrapatellar tendon longitudinally, detaching the outer or viciously pulling half from the tubercle of the tibia, passing this detached half beneath the intact inner or benign half, and suturing it subperiosteally to the tibia on the inner side. MacAusland and Sargent's modification, which they prefer, consists in detaching a small portion of bone with the outer half of the

86 Doelle Arch f klin Chir **118**, 1922

87 Roello Chir de Org di Mov, April, 1922

88 Meadows Northwest Med, July, 1922

89 MacAusland and Sargent Surg, Gynec & Obst, July, 1922

tendon, and inserting it in a bony pocket prepared on the inner side of the tibia

[ED NOTE—This suggested modification seems sound to the Editors, as offering perhaps a firmer attachment. The important point remains that, by this method of tenoplasty, occasionally supplemented by a correction of a commonly coexisting rotary knock knee deformity, recurrence of this crippling dislocation has been entirely prevented.]

#### FRACTURES

*Fracture of the Capitellum and Trochlea*—Lindem<sup>90</sup> describes a rather rare injury to the humerus at the elbow (seventeen cases in the literature) in which the articular face of the bone is split off by a fracture through the cancellous bone. The cause seems usually to be a fall on the outstretched hand or a blow on the dorsum of the upper third of the forearm, the force being transmitted through the radius and ulna. As a rule, the fragment is displaced anteriorly within the capsule, so that the articular surface faces forward. Lindem considers that excision of the displaced fragment is usually necessary. In two of Lindem's three cases, this was followed by a good functional result. The third patient refused operation.

*Fracture of Lower End of Radius Associated with Fracture or Dislocation of the Lower End of Ulna*—Homans and Smith<sup>91</sup> report six cases of these rather frequently associated injuries. They consider that the initial difficulty in reduction is due to several factors: 1. The loosening of the radio-ulnar articulation, which destroys the fulcrum, by which the forced inversion of the hand might pry loose and draw down the displaced lower radial fragment. 2. The pull of the pronator quadratus, drawing together the lower 2 inches of the radius and ulna, offering a most effective resistance to any leverage made. 3. The fact that straight traction can be made only on the hand, and not directly on the radial lower fragment. It is possible also that interposed muscle (pronator quadratus or supinator longus) may in certain cases prevent reduction, but this has not been demonstrated in the operations in the authors' series. The ultimate and postoperative difficulty in holding the fractured radius is undoubtedly due to the instability of the lower fragment of the ulna, not to the possible fracture of the ulna at the level of the break in the radius, but the tearing off of the ulna at its articulation with the radius, resulting in a rupture of the strong interarticular fibrocartilage. They consider that open operation is nearly always necessary to replace the radial fragments and that, in

<sup>90</sup> Lindem. *Ann Surg*, July, 1922.

<sup>91</sup> Homans and Smith. *Boston M & S J*, Sept 14, 1922, p 401.

instances in which the lower attachment between the radius and ulna is severed, secondary displacement and deformity are prone to occur

*Backfire Injuries*—Bizarro,<sup>92</sup> from an analysis of the records and roentgenograms of 190 cases of backfire injuries, concludes that (1) the commonest single lesion is a crack through the epiphyseal line of the radius, (2) the commonest double lesion is a fracture through the epiphyseal line plus a fracture of the ulnar styloid, (3) the carpal bone most commonly injured is the scaphoid, (4) violence is usually of the indirect type

*Traumatology of the Carpus*—Bizarro<sup>93</sup> has also studied 123 cases of injury of the carpal bones, finding that in 106, or 86 per cent, the scaphoid was fractured. This was the only lesion in sixty-eight, or 55 per cent, and it was a combined lesion in thirty-eight, or 30.9 per cent. There were two cases of fracture of the semilunar, six of the os magnum, and four of the unciform. Only twenty-seven of the fifty-five simple fractures of the scaphoid were seen within a week of the injury, but Bizarro believes that in such cases the wrist should be fixed in hyperextension, with the thumb included, for four weeks. He thinks fractures of the scaphoid rarely unite in spite of prolonged immobilization, but if seen early and properly treated, result in no disability. Old untreated fractures are of bad omen.

*Direct Traction on the Pelvis*—In injuries of the pelvis, Block<sup>94</sup> has employed direct traction by means of wire passed through one or both ilia, with excellent results. In combination with direct skeletal traction on the femoral condyles, Block believes the method applicable for old luxations of the hip joint, extreme overlapping of the femur and limb lengthening operations.

*Fractures of the Neck of the Femur*—Two German articles by Schmieden<sup>95</sup> and Bonn<sup>96</sup> advocating radical operative treatment of almost all intrascapular fractures of the neck of the femur are worthy of note in contrast to a review of the results of treatment by the Whitman abduction method by Powers<sup>97</sup>. These German surgeons advocate nailing or pegging when the capsule is not too badly separated and the central fragment is attached to it. They propose excision of the head in all other cases, placing the trochanter in the acetabulum, striving in older cases for an ankylosis, and in the younger, for motion. These surgeons have evidently had no experience with the abduction method

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<sup>92</sup> Bizarro. *Ann Surg*, July, 1922

<sup>93</sup> Bizarro. *Surg, Gynec & Obst*, May, 1922

<sup>94</sup> Block. *Arch f klin Chir*, July 21, 1922, p 410

<sup>95</sup> Schmieden. *Munchen med Wchnschr*, 1922, No 14, p 526

<sup>96</sup> Bonn. *Arch f klin Chir* 120 298, 1922

<sup>97</sup> Powers. *Wisconsin M J*, Aug, 1922

and have perhaps been influenced by such reports as that of the British Fracture Commission covering several hundred cases treated by Buck's extension, long lateral splints, wire mesh, etc. Only 23 per cent of these cases were considered to have favorable results, and Walker of the New York Bellevue Service and Scudder of Boston consider good only 12 or 13 per cent of results by these methods. When we compare the results of the Whitman abduction method reported by Campbell, 95 per cent good results in seventy cases, by Anderson, 95 per cent in 200 cases, and by Powers, 93 per cent in sixteen cases, ten of which were obtained in patients over 60 years of age, it would seem to indicate that there is no need, in the vast majority of patients of any age, of resorting to open operation.

*Necrosis of the Proximal Fragment in Fracture of the Neck of the Femur* —Axhausen<sup>98</sup> has had an opportunity to examine histologically a specimen of a fractured femoral neck in a boy of 16. The fracture had occurred ten months before his death from an intercurrent disease. Clinically and roentgenologically, bony union had taken place. The histologic examination revealed a complete necrosis of the central fragment, with a partial transformation into living bone proceeding from the distal fragment. The necrosis of the articular cartilage was leading to an arthritis. If such a change was taking place in a youth, with apparent firm union, it is easy to explain the changes which occur so often in older cases under pressure of weight bearing, such as secondary displacement of the head and absorption of the head and neck.

*Muscle Interposition A Cause of Delayed Union in Fractures of the Femur* —Kidner and Lakoff<sup>99</sup> treated a series of seventy-one cases of fracture of the femur between January, 1921, and April, 1922. Open operation, except for sepsis existing before the case came into their hands or for debridement in compound fractures, has been performed by them for only one reason, namely, because they believed that the interposition of muscular or fascial tissue made end-to-end apposition impossible and would be likely to delay or prevent union. They conclude that (1) if the fragments of a fractured femur are not brought into actual bony contact, as demonstrated by roentgenograms taken in two planes, under properly applied traction within three or four days, the case should be viewed with suspicion, (2) if specially planned methods are not immediately thereafter successful, manipulation under an anesthetic should be the next step, with an attempt to disengage the fragments from the muscle, success being appreciated by clean-cut

<sup>98</sup> Axhausen Arch f klin Chir **120** 325, 1922

<sup>99</sup> Kidner, F C and Lakoff, C B Muscle in Interposition Cause of Delayed Union in Fracture of Femur J A M A **79** 200 (July 15) 1922

rubbing of the bony fragments on one another, (3) if after such manipulation and the reapplication of traction, apposition is still lacking, as shown by roentgenograms, open operation should be undertaken, (4) at open operation, the muscle or fascial bands are cleared, and if end-to-end apposition of the interlocking type is possible, only external splinting is necessary. If there is a tendency toward displacement of the fragments, the authors have employed Gallie's beef-bone plates and screws, Magnuson's ivory screws, and, occasionally, metallic plates and bands. They believe the application of these forms of internal splints is more simple and sure than bone grafting.

*Spinal Fracture of the Tibia and Fibula*—Caldwell's<sup>100</sup> experience with spiral fractures of the tibia and fibula leads him to believe that it is only possible to obtain complete anatomic replacement by operative measures. Manipulative reduction, and, in two cases, heavy continuous traction by means of ice tongs applied to the malleoli, totally failed of satisfactory results. The author favors banding with the Parham Martin band. Postoperative splinting is considered unnecessary. He reports ten such cases of fracture, two of which were treated conservatively, with poor results, and eight by operation, seven with good results. In the latter group, two patients developed serious post-operative complications, one, a severe infection, later necessitating a resection of 3 inches of the tibia, and the second a nonfatal pulmonary embolism and phlebitis of both legs.

[ED NOTE—The Editors are unable to agree with Caldwell that reposition in spiral fractures of the tibia and fibula can be obtained only by open reduction. Their own experience with the treatment of such cases by the early application of continuous skeletal traction (a pin passed above the os calcis) in conjunction with the Thomas splint, has been so favorable that, in an active fracture service in a large general hospital during a period of two years, open reduction was necessitated only once among all the simple fractures involving the shafts of the tibia and fibula of whatever type.]

*Posterior Dislocation of the Foot with Posterior Marginal Fracture of Tibia*—Thomas<sup>101</sup> contests the commonly held view that posterior dislocation of the foot occurs as a result of Pott's fracture, with widening of the ankle mortise. That it is a frequent complication of Pott's fracture is not disputed, but its occurrence is only made possible by a posterior marginal fracture of the lower articular surface of the tibia, which may exist alone, but is frequently associated with other ankle fractures. A posterior oblique fracture of the lower end of the fibula is also a frequent accompaniment. The displacement tends to

<sup>100</sup> Caldwell Ann Surg, June, 1922

<sup>101</sup> Thomas Surg, Gynec & Obst July 1922



recur unless, following reduction, the foot is locked in strong dorsiflexion. Turner attributes the erroneous conception of the lesion to clinical observations preceding the use of the roentgenogram, when the feature of posterior displacement of the foot was recognized but the accompanying marginal fracture was overlooked.

[ED NOTE—The Editors are inclined to agree with Thomas in this matter, as they have yet to see such a dislocation without accompanying marginal fracture. Nevertheless, the old teaching remains unchanged, that in ankle fractures we must always be quick to recognize and correct posterior displacement of the foot.]

*Injuries to the Astragalus*—Lotsch<sup>102</sup> brings out two rather interesting facts in an article on these rather rare traumatic lesions, namely, that compression fractures of the astragalus often take place as a result of falls of a considerable distance, striking on soft ground, whereas, if the surface is hard, compression fractures of the os calcis occur. Extreme plantar flexion may bring about a fracture of the posterior portion, and in such cases, a helpful sign is likely to be severe pain and tenderness along the tendon of the flexor longus hallucis.

*Metatarsal Fractures*—Both Jacobson<sup>103</sup> and Vogel<sup>104</sup> call attention to the frequently unrecognized fractures of the metatarsal bones, which may occur from slight trauma or from no known direct trauma. One of the resulting difficulties is the disturbance of the transverse arch. Special foot supports are necessary.

*Calcium and Phosphorus Metabolism in Patients with Fracture*—Tisdall and Harris<sup>105</sup> make a report of several years' work on the problem of the deposition of bone in fractures. Their conclusions are as follows: 1. The inorganic phosphate content of normal serum from birth to 20 years of age is remarkably constant. At 20, it drops sharply to a lower concentration and is again remarkably constant at this level throughout adult life. 2. The drop in the phosphate content of the serum at the age of 20 corresponds to the period of cessation of bone growth. 3. During the period of union of fractures in adults, the phosphate content of the serum is raised to a level approximately the same as that present in childhood, i. e., the period of active growth. 4. There is a close parallelism between the concentration of inorganic phosphate in the serum and the deposition of new bone, during both the period of growth and the period of repair of fractures. 5. In addition to the increase which occurs in the inorganic phosphate content of the serum

102 Lotsch. *Klin Wchnschr*, Feb 2, 1922, p. 318.

103 Jacobson. *Zentralbl f Chir*, 1922, No 4, p. 116.

104 Vogel. *Zentralbl f Chir*, April 15, 1922, p. 505.

105 Tisdall, F. F., and Harris, R. I. *Calcium and Phosphorus Metabolism in Patients with Fractures*, J. A. M. A. 79: 884 (Sept. 9) 1922.

during the union of fractures, there is a local metabolic process at the site of the fracture, which is probably even more important for the production of union than the increased phosphate content of the blood serum. In some of the animal experiments, this latter phenomenon was especially brought out. In one animal in which the apposition of the fragments was by chance reasonably accurate, there was union, while in the others, there was nonunion. Administration of calcium phosphate or yellow phosphorus or cod liver oil showed a rise in the phosphate content of the serum similar to that seen in the clinical cases of fracture examined. The administration of the various drugs did not appear to modify these curves to any appreciable degree. As in the clinical cases, the calcium curves showed only slight alterations.

*Outline of the Treatment of Fractures*<sup>106</sup>—In the January, 1923, number of the ARCHIVES OF SURGERY is published an outline of the treatment of fractures, representing the conclusions of a group of general, orthopedic and industrial surgeons of large experience in the treatment of fractures in civil and military practice. The purpose of this conference, held in Boston under the auspices of the Fracture Service of the Massachusetts General Hospital, was to ascertain whether such a group, without previous consultation and trained in different schools of experience, could agree on such an outline of treatment. Somewhat to the surprise of all those present, it was found that, except for certain minor and generally unimportant details, they agreed. The outline above referred to presents their findings. This is not an attempt to standardize the treatment or to discourage in any way new methods or hold the experienced surgeon to any single method, but rather to place a helpful outline of treatment of proved worth in the hands of the general practitioner, who, as the industrial compensation cases show, is at present often giving his patients with fractures neither sound initial nor sound after treatment. For this purpose, as well as in the teaching of treatment of fractures, this well illustrated outline will prove, we believe, very useful.

#### AMPUTATIONS

*Kineplastic Amputation of Forearm*—Bosch Arana<sup>107</sup> of Buenos Aires has written on the subject of kineplastic amputation of the forearm. He has been able to produce three active motors in the stump of the forearm, and hopes to be able to develop a prosthesis in which one motor will flex the fingers, the second extend them, and the third control the movements of the thumb.

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106 Outline of Treatment of Fractures, Arch Surg 6 172 (Jan) 1923

107 Bosch Arana Surg, Gynec & Obst, Sept, 1922, p 347

[ED NOTE—That utilization of the muscles and tendons of an amputation stump to activate a prosthesis is possible had been demonstrated repeatedly. However, this work is still in an experimental stage, and much is yet to be done to make it practical. The chief difficulty up to the present has been the failure to develop appliances of sufficient mechanical perfection to be really useful. Considerable work is being done on this subject in Europe, and especially in Italy, where Putti has at his disposal admirable workshops and skilled mechanics. The Editors believe that the problem will be solved, but only when the surgeon is working in absolute harmony with skilled appliance makers who can carry out his ideas. Kineplastic operations performed under other conditions are at present bound to result unsatisfactorily, and this is likely to throw discredit on the entire procedure.]

#### INDUSTRIAL SURGERY

*Acute Painful Back Among Industrial Employees Alleging Compensable Injury*—Conn,<sup>108</sup> after a rich experience with the problem of "backache" in industry, is convinced that the first duty of the surgeon is to make a correct diagnosis. After analyzing 156 cases, he suggests the following diagnostic classifications: 1 Traumatic strain 2 Postural strain 3 Sprain 4 Sacrolumbar lesions 5 Sacro-iliac lesions 6 Infectious myositis. He believes trauma is not the important etiologic factor in a large percentage of backaches from alleged trauma. On the other hand, malingering, he believes, is uncommon, although implied to the surgeon by the patient's conception of the etiology and his over-anxiety to obtain recognition of a real disability. Persons presenting osseous abnormalities in the lower portion of the spine are a potential group, especially susceptible to violence, but capable of developing disability unexcited by trauma. Conditions of sacro-iliac relaxation are of infrequent occurrence in industry. Sacrolumbar lesions include two classes as regards involvement of the articulation, extrinsic and intrinsic, the latter representing the grave traumatic lesions of most common occurrence.

[ED NOTE—The Editors believe that this analysis of Conn, based on experience and careful observation, is valuable. They find themselves in essential accord with his conclusions.]

*Back and Foot Strain in Industry*—Wilson,<sup>109</sup> in a well illustrated article, reviews the etiology of these conditions from the standpoint of anatomy, physiology and body mechanics, outlining his ideas as to methods of diagnosis and treatment. He makes an important suggestion which, if adopted, would, in the opinion of the Editors, materially

108 Conn, H. R. *Acute Painful Back*, J. A. M. A. **79** 1210 (Oct. 7) 1922.

109 Wilson, J. *Indust. Hygiene*, July, 1922.

diminish the number of chronic and discouraging cases of disability arising in industry. This suggestion is that, as a preventive measure, those who seek employment should undergo a routine physical examination by a well trained surgeon, who would grade them on the basis of body mechanics and susceptibility to strain. Those with marked physical defects should be required to undergo a period of corrective treatment with a view to improving their physical condition, permanent employment and higher wages being the reward of success. This would be applying to industry in a direct and entirely practical manner, the lessons learned in the war.

[ED NOTE—The Editors believe it would be a measure of economic importance also. Prevention is generally less expensive than cure, and an emphasis would be placed on physical fitness which would react favorably on the attitude of the employee toward his employer.]

*Traumatic Osteitis of the Wrist*—Rogers<sup>110</sup> reports four cases of rarefying osteitis of one of the carpal bones, the semilunar in three and the scaphoid in one. The condition has previously been described by Preiser, in 1910, who reports five cases, and by Guie in 1914, who reports seven personal cases, and who collected twenty-nine cases from other clinics. Preiser believes the lesion to be a rarefying osteitis from interference with the nutrient artery, while Guie considers the condition essentially a compression fracture analogous to the so-called Kummell's disease. In Rogers' cases, the onset of symptoms was gradual, generally covering a period of several months. There was definite pain referred to the wrist joint, brought on by use and relieved by rest. There was a slight amount of swelling associated with tenderness to pressure over the diseased bone. The limitation of motion occurred at first almost wholly in the direction of dorsiflexion. There was a question of trauma in all of the cases, but the symptoms began only after a considerable interval. In all, the roentgen ray showed the diseased bone "crinkled" in outline, smaller in size than normal, and with changes in the internal architecture. All of the cases were treated by excision, but two, only after a long period of conservative treatment. These two patients were relieved by conservative measures as long as they did not use the wrist, but the symptoms recurred as soon as they returned to their occupations. All the specimens were examined pathologically, and no evidence of tuberculosis was found. The cortex was thinned, the medulla contained much more fat tissue than normal, and there was loss of the normal bony trabeculae. The end-results are known in two of the cases and are reported as excellent. The writer suggests the name of traumatic osteitis of the wrist.

## RESEARCH

*The Free Transplantation of Fascia and Tendon*—Gallie and LeMesurier<sup>111</sup> have conducted a long series of experiments to test the value of fresh autogenous transplants in taking the place of ligaments and tendons. These transplants must be carefully sutured and interwoven to insure freedom from slipping, and the successful methods they have devised are illustrated. They report the late results in fifty cases. In every case, the transplanted tissue has held, and has fulfilled the purpose for which it was transplanted. This they attribute to their care in bringing raw surfaces of the transplant in contact with firm connective tissue. Union has seemed complete in three weeks. No silk or unabsorbable tissue has been employed in their sutures. They quite properly observe that it seems more natural to use as ligaments material which we know will live and retain its normal characteristics.

[ED NOTE—This work of Gallie and LeMesurier seems to us so careful and thorough, both from the point of view of an experiment and from the end-results. Their methods should have wide adoption, with assurance that success will be achieved if the principles of their technic are followed.]

*Experimental Production of Spasmodic Torticollis in Animals*—Rosenow<sup>112</sup> has obtained ticklike movements of the head and neck in animals as a common sequel to an encephalitis caused by the inter-cerebral infection of a somewhat atypical streptococcus isolated from cases of encephalitis. In these animals, the movements ceased during sleep, as the movements of a spasmodic torticollis do in human beings. They were also made worse by various forms of excitation. The type of movements in animals and in human patients were very similar.

*Pathology of Osteitis Deformans Paget's Disease*—Cone,<sup>113</sup> after extensive discussion of this subject, inclines to the belief that the changes in Paget's disease may be explained by a primary pathologic condition of the blood vessels like that observed in hereditary or acquired syphilis, with its accompanying bone changes, and such as is found on a small scale in chronic passive congestion or infections of a chronic character. He considers it not at all improbable that malaria, typhoid, influenza, erysipelas or parasitic organisms might induce such vascular lesions and be associated with a local or general osteitis deformans.

*Fetal Chondrodystrophy in a Calf*—Seifried<sup>114</sup> examined all the endocrine glands in a calf showing all the characteristics of a fetal chondrodystrophy. All the glands were hypoplastic, the most marked

111 Gallie and LeMesurier. *J Bone & Joint Surg*, July, 1922, p. 600.

112 Rosenow, E. C. *Experimental Production of Spasmodic Torticollis in Animals*, *J A M A* 78:752 (June 3) 1922.

113 Cone. *J Bone & Joint Surg*, Oct., 1922, p. 751.

114 Seifried. *Munchen med Wchnschr*, 1922, No. 11, p. 417.

changes occurring in the thymus, the cortex of which was markedly increased, with a diminished number of Hassall's bodies. The eosinophils and plasma cells were also much diminished, indicating also a hypoplasia of the thymus.

*Observations on the Normally Developing Knee*—Cohn,<sup>115</sup> continuing his already reported studies of the ossification of the bones of the elbow and shoulder, now reports his observations on the growth of the bones of the knee. The epiphyses of the lower end of the femur and of the upper end of the tibia have attained the size of half the width of their respective diaphyses at 1 year. There is evidence of ossification within these epiphyses at a much earlier time. During the first four years, no other epiphyses are evident roentgenologically. At 5 years and 4 months, ossification has proceeded to such an extent in the lower end of the femur and the upper end of the tibia that it almost covers their respective diaphyseal ends. At this age, for the first time, there is ossification in the upper epiphysis of the fibula and within the patella. At 8 years of age, the depressions for the semilunar cartilage and the spines of the tibia are evident roentgenologically. By the tenth year, there is a close approximation between the respective epiphyses and their diaphyses. At 10 years and 11 months, we see the first evidence of the tubercle of the tibia. It is represented by a downward projection from the upper epiphysis of the tibia. During the twelfth year, the tubercle increases rapidly in size, and projects forward, being separated by a wide space from the shaft of the tibia. Union between the tubercle and the shaft proceeds from above down, and from before backward. At 18 years, this tubercle is completely ossified and united to the shaft. In one instance, the tubercle of the tibia seems to be ossifying through two separate centers. At 15 years and 4 months, there seems to be complete ossification within the epiphyses, and union of the respective epiphyses and their diaphyses. After the fifteenth year, there seems to be complete ossification of epiphyses and diaphyses.

*Bone Atrophy*—Brooks<sup>116</sup> studied the process of bone atrophy in material obtained from patients suffering from poliomyelitis, traumatic nerve injuries, tuberculosis of bone, fracture, acute pyogenic osteomyelitis, deformities acquired and congenital and other conditions in which one extremity had not been used, also bones of animals in which function of one extremity had been impaired by nerve section, joint injury, or simple fixation by a plaster cast. In all instances, the bones of the nonused extremity were compared with the bones of the used extremity. The bones were studied in gross, by roentgen ray, microscopically, chemically and physically. In all instances, the changes were the same,

115 Cohn, Isadore. Normally Developing Knee, Arch Surg 5 395 (Sept) 1922

116 Brooks. South M J, Oct 1922 p 823

regardless of the cause of the nonuse, thus indicating that there is no necessity for assuming that any factor other than lack of function was responsible. In other words, the bone atrophy that follows a nerve injury is not the result of "trophic" influences, and that following an acute osteomyelitis is not the direct result of the toxins of the organisms, but in each instance, atrophy is the result of lack of function in the extremity, just as it follows the simple fixation of a normal extremity in a plaster cast. Bone changes make their appearance in a very few days after the cessation of function of an extremity. In the experimental animal, well marked changes are found after ten days of nonuse. The changes progress rapidly and are very marked in from ten to twelve weeks. Apparently, a maximum is reached in from six to twelve months, beyond which point there is very little change. In the adult, nonuse makes the bones become lighter and more fragile. The length is unchanged. The diameter is only slightly decreased. The diameter of the medullary canal is markedly increased. The trabeculae of the cancellous bone of the epiphyses become much thinner, and in many areas they disappear completely. After long periods of nonuse, the compact bone of the shaft becomes cancellous. The chemical composition of the entire bone is changed markedly. There is loss of mineral constituent and an increase in the proportions of organic material. It therefore follows that lack of function affects the size, shape, weight, roentgen-ray appearance and strength of bones by a change in the amount of matrix present, but the characteristics of bone tissue are not changed. The change is quantitative and qualitative. The end-result of constant lack of function during the growing period of a bone of an extremity is a bone which is relatively shorter and smaller. The relative size of shaft and epiphyses is changed, in that the shaft is relatively smaller than the epiphyses. The densities of the compact bone of the shaft and of the cancellous bone of the epiphyses are about normal. The chemical composition and physical characteristics of the bone are the same as in normal bone. The property of regeneration of bone is a property of the bone cell and not of the bone matrix. From a clinical study of the repair process in atrophied bones and a careful study of transplants of bones in animals in which transplants of atrophied bone have been compared to transplants of nonatrophied bone, it was not possible to detect any difference in the regeneration power of these two types of bone transplants.

*Pathologic Changes in Muscle as a Result of Disturbance of Circulation. Experimental Study of Volkmann's Ischemic Paralysis—*Brooks<sup>117</sup> has also conducted a very complete and interesting series of

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<sup>117</sup> Brooks. Pathologic Changes in Muscle as a Result of Disturbances of Circulation. An Experimental Study of Volkmann's Ischemic Paralysis, Arch Surg 5 188, July, 1922

animal experiments to determine the effects of various types of circulatory obstruction on muscle, with special reference to the cause of Volkmann's ischemic paralysis. A review of the literature on this subject permitted the conclusion, based on clinical evidence, that there is a condition of paralysis of the muscles which appears, following circulatory obstruction, and which is independent of injury to the nerves. The clinical appearance suggests the presence of gross changes in the muscle, and pathologic examination of the tissue by other observers revealed the muscle cells in large part degenerated and replaced by fibrous tissue. The various experiments which were conducted and the results obtained were as follows:

**EXPERIMENT 1** (Three animals)—The circulation of the leg was obstructed by application of a tight bandage above the elbow for periods varying from five to twenty-four hours. In one animal, no effect was produced on muscle function, and in the other two the limb was paralyzed, but the cause was found to be an injury to the nerves from direct pressure.

**EXPERIMENT 2** (Three animals)—Permanent obstruction of the primary arteries of the limb was obtained by ligation of various arteries. In two animals, this resulted in complete temporary loss of muscle function associated with superficial gangrene. Pathologic examination showed the muscle either pale and totally necrotic, or else of healthy appearance and with contractile response. The areas of muscle degeneration were sharply defined and the inflammatory reaction was slight. Between the extremes of normal muscle and totally necrotic muscle, there was no intermediate area in which the muscle still lived but could not function. One animal showed the phenomena of typical intermittent claudication, which disappeared at the end of three days, when a collateral circulation was reestablished.

**EXPERIMENT 3** (Three animals)—Temporary obstruction of the primary arteries of the limb was obtained by ligation of certain arteries combined with the application of clamps to others, the latter being removed at the end of periods varying from six to twenty-four hours. Arterial obstruction of six hours resulted in temporary interference with function, followed by rapid recovery on removal of the clamps. Obstruction for periods of from seventeen and twenty-four hours resulted in complete paralysis below the knee, but the nerves were uninjured. Pathologic examination revealed sharply defined areas of degeneration in the muscle, accompanied by edema and hemorrhage, but the tissue was either completely necrotic or completely viable, and inflammatory reaction and fibrosis were lacking.

**EXPERIMENT 4**—This was a series of experiments with isolated muscle. The same procedure of isolating the muscle (rectus femoris) was followed throughout. By operation, the muscle was completely freed from all surrounding tissue except at its origin and insertion, and these attachments were then ligated. The artery, vein and nerve were isolated from the surrounding tissue and preserved for treatment thus. A section of nerve (artery and vein intact). This resulted in paralysis of the muscle. At examination, the muscle fibers were found diminished in size and showing loss of definition of striation.



There were occasional degenerated fibers. There was no evidence at the end of a month of inflammatory reaction or fibrosis. The process was one of atrophy rather than degeneration. B Injection of blood into muscle. In two animals, the artery, vein and nerve were left intact, and the muscle was distended by the injection of blood. In another animal the artery was, in addition, ligated. No abnormality in the muscle reaction resulted, and at the end of one month there was no evidence of inflammatory reaction or fibrosis. C Ligation of artery (vein and nerve intact). There were eleven experiments, the animals being killed at intervals ranging from seven to seventy days. The muscle showed normal physiologic properties in all instances, and in none did the muscle become fibrous. There were slight degenerative changes occasionally, but no inflammatory or fibrous reaction. In five other animals, the artery was ligated, and in addition the general circulation of the limb was diminished by ligation of various branches of the aorta. This resulted in edema of the muscle, but only slight degenerative change and inflammatory reaction. Further diminution of the blood supply of the limb resulted in complete absorption and disappearance of the muscle. D Ligation of vein alone. There were nineteen experiments, the animals being killed at periods varying from one to 120 days. The procedure resulted in a constant pathologic change in the muscle. This change was characterized by an initial period of acute inflammatory changes in the muscle and subsequently by the development in the muscle of an extensive fibrosis. The fibrosis in some instances replaced a large portion of the muscle fibers and decreased very markedly the power of the muscle. In other instances, the substitution of the muscle fibers by fibrous tissue was complete.

The constancy of the pathologic process and the certainty with which it follows the experimental method described are important points. The author concludes from this large series of experiments that a muscular weakness associated with a certain stiffness which follows the occlusion of a large artery may be a phenomenon of ischemia. It would be likely to improve with the development of a more adequate circulation. A complete paralysis following the occlusion of an artery is evidence of an anemia, and usually signifies impending gangrene. Anemia and inflammation are incompatible processes. Any condition which develops within from twenty-four to forty-eight hours and which is characterized by heat, swelling, pain and a subsequent fibrosis cannot be the result of permanent occlusion of an artery. That the classic picture of Volkmann's ischemic paralysis could be explained only on the basis of acute venous obstruction would seem quite clear. Probably, some of these cases may be the result of pure local pressure necrosis analogous to the decubitus ulcer or pressure sore over the heel from continuous pressure, but it should be a simple matter to differentiate such cases from the others.

#### MISCELLANEOUS

"Flat Hand"—Goldthwait<sup>118</sup> again calls attention to the importance of the carpal arch, describing carefully the anatomy of this structure,

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118 Goldthwait J Bone & Joint Surg, July, 1922, p 469

and the necessary part which it plays in proper functioning of the hand. When this arch "flattens," the palmar tendons are no longer held in place by the hook of the unciform and the trapezium, and weak and painful action results. By a light wrist strap with two pellets, one on either side of the trapezium, and a thumb loop to retain the strap in place, the arch may be restored and function rendered painless.

*Tennis Elbow*—Romer<sup>119</sup> maintains that there are three types of the so-called tennis elbow. 1. The commonest type, in which a condition analogous to a tenosynovitis exists in the muscles attached to the condyles, usually the external. He considers that this is caused by the frequent jerks of the muscles at their origin, and he speaks of it as a traumatic fibrosis. 2. A type in which the tender point is on the condyle itself, owing to irritation of the periosteum, suggestive of a minute tear of some muscle insertions. 3. A synovitis of the radio-ulnar joint. These three varieties, Romer suggests, may be stages rather than actual types. Romer believes that the use of a large handled or heavy racket is the commonest cause, unless the player has a correspondingly large hand or strong arm. His treatment consists of massage for from ten to twelve days and strapping of the forearm in such a way that the pull of the muscles on their origins at the external condyle is checked. Play should be begun with this strapping in place.

[ED. NOTE—We recognize that there is a condition more or less accurately described as epicondylitis, in which the tenderness is over the bony condyle, and the roentgen ray may show evidence of periosteal reaction and lime salt deposit. This condition is relatively rare, and is not induced, we believe, by tennis or other sports or occupations in which muscle action and not direct trauma is the etiologic factor. We believe that the hypothesis of a traumatic fibrosis, analogous to a tenosynovitis, at the origin of the muscles attached to the external condyle, is not necessary, nor is more than clinical evidence advanced by Romer to bear it out. Neither have we ever found any evidence of a true radiohumeral synovitis. When the muscles originating from the external condyle and the supinator brevis are relaxed the motion of this joint has in our cases been painless. The condition seems to us more satisfactorily explained by a bursitis in the small bursa, demonstrated by Osgood<sup>120</sup> to be usually present beneath the conjoined tendon and supinator brevis and directly over the radiohumeral joint. This bursa has been found distended in cases of this affection at operation, and its evacuation and curetting have been followed by relief of symptoms.

119 Romer. *Lancet* July 8 1922

120 Osgood, R. B. Radiohumeral Bursitis, Epicondylitis Epicondylarum (Tennis Elbow). *A Personal Experience*. *Arch. Surg.* 4:420 (March) 1922

*Myositis Ossificans*—Ferrarin<sup>121</sup> reports nine cases of myositis ossificans, five of them in the region of the elbow, three of them following dislocations. The ages varied from 15 to 30 years. The tumor mass grew smaller under rest in all cases, but in none did it disappear. He believes the condition is due to a chronic irritation of the interstitial tissue.

*Isolated Disease of the Head of the Second Metatarsal Bone*—Axhausen,<sup>122</sup> in examining two specimens of that peculiar isolated disease of the head of the second metatarsal bone described by Kohler and others, found that the largest part of the head had become necrotic. In some portions, a fibrous substitution of the necrotic bone was seen, with an active reaction of the synovial membrane like that in the proliferative type of chronic arthritis. A direct traumatic etiology is suggested neither by the histories nor the histologic findings, and Axhausen is convinced that the process is analogous to osteochondritis dissecans, which the author believes to be caused by an embolic mycotic process.

*Vaccine Therapy in Bone Lesions Due to the Typhoid Bacillus*—Vincent<sup>123</sup> has compiled thirty cases of typhoid and paratyphoid osteopathies treated by vaccine therapy, and adds one of his own as a convincing example of the efficacy of this form of treatment in many cases. His patient was a young woman who developed a series of abscesses, several osteomyelitic bone lesions and a mucomembranous enteritis during a convalescence from a fever supposed to be typhoid, but whose blood agglutinated the paratyphoid bacillus. She was given four injections, representing a total of 2,500 million bacilli, and all bone and other lesions promptly cleared up, although they had existed for three months before the vaccine therapy was instituted.

*Lordotic Albuminuria with Pott's Disease*—Neukirch and Rottmann<sup>124</sup> describe an interesting case of a young woman with a large tuberculous kyphos, including the sixth to the eighth dorsal vertebrae, and a very marked lumbar lordosis in the upright position. When the patient was upright, there was albuminuria. This ceased promptly when the lordosis was corrected by posture. Ureteral catheterization proved beyond doubt that only the left kidney was responsible for the albuminuria, seeming to prove that the phenomenon has been correctly explained as due to a congestion of the veins in the left kidney.

*Progress in the Care and Education of Crippled Children in Ohio Under New Laws*—Chollett's<sup>125</sup> report of progress in the development

121 Ferrarin. *Chir d'org di movimento*, July, 1922.

122 Axhausen. *Beitr z klin Chir* 126:451, 1922.

123 Vincent. *Bull de l'Acad de med Paris*, May 9, 1922, p 517.

124 Neukirch and Rottmann. *Klin Wchnschr*, March 11, 1922, p 523.

125 Chollett, B. G. *Care and Education of Crippled Children*, J. A. M. A. 79:1297 (Oct 14) 1922.

and organization of a movement originated and still fostered by the Rotary Clubs of Ohio for the care and education of the crippled children of the state is most encouraging. State laws have been passed, a large central committee has been formed to have supervision of the work, and educational propaganda has been started in order to bring to the attention of the public the advantages of proper treatment for various types of cripples.

*Scope of Occupational Therapy and Training of Occupational Aides*—Brackett,<sup>126</sup> in discussing the scope of occupational therapy, describes the minimum requirements in the Boston School of Occupational Therapy for training in this rather new branch of medical work (1) an age of from 24 to 40, with at least a high school or equivalent education, and (2) an occupational therapy school course of one year of twelve working months. Nine of these months are spent in the school, where applicants are taught major and minor crafts for practical work and are given courses of a varying number of lectures in anatomy, neurology, mental hygiene and diseases, orthopedic surgery, contagious disease, tuberculosis, syphilis, psychology, social service, physiotherapy, hospital ethics and management and personal hygiene. Three months of the twelve are spent in practical work in hospitals under supervision. After a year or more work in hospitals or with groups of patients, these graduates may apply for registration by the Massachusetts Society of Occupational Therapy.

*Quackery, Miracle Healing and Medical Cults*—Lovett,<sup>127</sup> in an interesting article, reviews the history of quackery and miracle healing, and shows that irregular practice has always been and probably always will be with us in varying forms. In general, it follows well defined channels, as it rests on an inherent tendency in the human race to believe in the wonderful, the mystical, the obscure and the new. Today, Christian science and manipulative methods hold the center of the stage. If they were wiped out, some other form of irregular practice would take their place. Christian science developed under a wonderful woman who had a very practical understanding of advertising and business matters, but she is dead and her successors are quarreling. Osteopathy is in reality bone setting, with a pseudoscientific explanation superimposed, but chiropractic seems merely a cheap commercial enterprise modelled on osteopathy, too successful, too fast growing and too confident to endure permanently, although at present it is a real menace to the health of the community. Miracle healing and mental healing when associated in any way with religious belief cannot be argued about.

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126 Brackett Arch Occupational Therapy, June 1922

127 Lovett Boston M & S J July 15 1922 p 53

and may only be restricted to the extent of preserving the health of the community and safeguarding the avoidable deaths. With regard to manipulative methods, we should adopt the course already adopted by *The Journal of the American Medical Association*, and instead of excluding the literature of irregular cults from our libraries, we should give it the widest publicity, and encourage students and practitioners to familiarize themselves with it. Secondly, we should teach our students the principles of physical therapeutics and show them why manipulative methods are at times beneficial. In order to do this, we should investigate these manipulative methods ourselves.

#### BOOK REVIEWS

ORTHOPAEDIC SURGERY By Sir Robert Jones and Robert W. Lovett  
New York: William Wood & Co., 1922

This is a text and reference book of 700 pages, well illustrated. Under the heading of orthopedic surgery, there are included joints and their affections, bones and their affections, including ununited and malunited fractures, disturbances of the neuromuscular mechanism, congenital deformities, static and other acquired deformities, and the principles and details of apparatus. We believe this is the most important work dealing with these subjects which has yet been written in any language. Two eminent clinicians and investigators of wide experience, the one British and the other American, have succeeded in writing a book which is judicial in its attitude, meticulous in the credit it gives to other men's work, conservative in its tone, but practical and authoritative in its statements. The book is a contribution to general as well as orthopedic surgery, the latter of which the authors recognize as only a special branch of the former. To orthopedic surgeons, and especially to teachers of orthopedic surgery, the book is most welcome.

BODY MECHANICS AND HEALTH By Leah G. Thomas and Joel E. Goldthwait  
Boston: Houghton, Mifflin Company

The demand has long been felt for a book enunciating the principles which underlie the close association between proper use of the body and good health, and describing in detail the exercises and rest positions best calculated to bring about correct posture. This little book, well illustrated, and written quite as much for teachers of physical training as for physicians, is likely to supply this demand. It is a distinct contribution to orthopedic surgery, especially if one derives the word from *παιδεύω* and *ὀρθός*, "to educate straight."

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